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# TELEVISION

By

ALFRED DINSDALE

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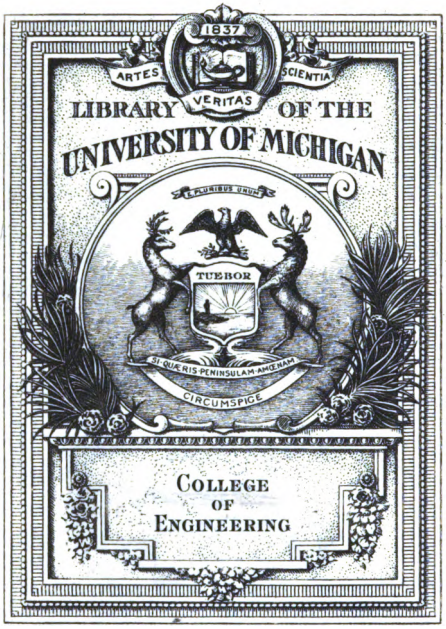


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# TELEVISION

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JOHN L. BAIRD.

[*Frontispiece.*

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# TELEVISION

BY

ALFRED DINSDALE, A.M.I.R.E.

(EDITOR OF THE *TELEVISION MAGAZINE*)

WITH A FOREWORD BY

DR. J. A. FLEMING, M.A., D.Sc., F.R.S.

LONDON

TELEVISION PRESS, LTD.

1928

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# FOREWORD

THE subject of television may be now said to be a "live" one. It has passed out of the region of merely imperfect or curious laboratory experiments, which attract only the professed physicist or experimenter, into that of practical demonstration.

Hence it has begun to interest the general public, who attach no great importance to purely scientific investigations or new phenomena, but only to that which possesses in their view a practical value—by which they mean contributing to the convenience of life, or to its amusement, or to the dissemination of information and news.

In the history of all such inventions as the telephone, wireless telegraphy, and television, we find two stages of development. There is first an idea and the more or less unsuccessful approach to a realisation of it. Then some inventor, such as a Bell, a Marconi, or a Baird, makes an invention or discovers a new device, often very simple, which at one stroke opens up a new pathway to accomplish-



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ment; and after that progress becomes assured and rapid. When once the right clue has been obtained, definite achievement is often a matter of systematic experiment and financial expenditure.

There can be little doubt that such a clue has been obtained to the solution of the problem of transmitting to a distance, either by wire or by wireless, the image of moving objects, as contrasted with the already solved problem of the reproduction of a photograph or picture at a distant place.

True television means being able to see, by electrical methods of transmission, the reproduction on a screen of the image of moving, living, or stationary objects which are at a great distance from the observer.

It is therefore convenient at this stage to have information collected in a single volume which deals with the history of unsuccessful or previous researches as well as with the appliances which have led to success in solving the problem.

This information is scattered about in periodicals and proceedings not very accessible to the general reader. Mr. Dinsdale has therefore performed a very useful service in collecting it in this book, which is at once interesting, informative, and historical.

He gives the bulk of his space to the achievements of Mr. J. L. Baird, but he does

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not neglect to do justice to the work of previous or contemporary workers.

The special problems which enter into the solution of the general problem of television are dealt with chapter by chapter.

The reader who comes to the subject without much preliminary knowledge of physics will have no difficulty in understanding the nature of the appliances and the difficulties involved in television.

Broadly speaking, the problem of television is as follows: Every object illuminated by light reflects irregularly from each small area of its surface rays of light of a particular intensity and wave-length depending on the nature of the surface. Disregarding the so-called colour of the surface, which determines the wave-length of the reflected light, we have a certain intensity of light reflected from each small patch of the surface of the object. By means of a device called a photo-electric cell, we can make this light received on it produce an electric current which is proportional to the intensity of the light; and therefore to the brightness of the patch in the object from which it proceeded.

This current can in turn be made to vary the brightness of the glow on a plate in a certain kind of lamp called a neon lamp, and the image of a small piece of this glowing plate can be projected on a screen.

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The problem then resolves itself into one of exact timing. We have to select in turn every little patch of the object and produce on the receiving screen other little patches of light which are exact imitations in brightness and relative position of those selected in the object.

The patch of light on the receiving screen is made to run to and fro so as to cover in turn every point on a little screen, varying in brightness as it moves. If the complete excursions of this spot of light are completed in less than one-tenth of a second, then, owing to the persistence of vision, or the lingering of an impression made on the retina of the eye for a short time, we see the reproduced image as a whole, whether the object is at rest or in motion, and hence achieve television.

So far the result has been the more or less perfect, but recognisable, reproduction of the face of a human being by means of electric-current transmission or electric-wave transmission by wireless at distances up to 3,000 miles or so, as described by Mr. Dinsdale.

The great obstacle to wireless television lies not so much in the television apparatus itself, as in the disturbances caused by fading, Morse signals, atmospherics, and other causes which mutilate also wireless broadcasting of speech or music.

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The overcoming of these obstructions is, however, largely a matter of the amount of power employed in the transmitter.

What the public chiefly wish to know is whether it will ever be possible for us to receive and see in our own homes the reproduction of distant events, such as the King going in State to open Parliament, or the exciting finish of the Derby race, just as we can at the present time hear by wireless the description by speech of such events. It may be said at once that there is no inherent impossibility in it; all inventions require time for their ultimate development and perfection.

Television now in 1928 is very much in the same stage of progress as wireless telegraphy was about the year 1900 or 1901. But it may not take nearly so long to bring it to practical perfection because many of the problems involved have been already solved.

Meanwhile there are other side lines of invention which seem to promise more immediate commercial results.

Just as in the modern electric-cut gramophone records the electric current from a microphone is made to actuate the cutting chisel on the soft, or master record, and yield the records which can reproduce the music or speech, so also we can use, as Mr. Baird has done, the amplified current from

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the photoelectric cell of a television transmitter to move this chisel and so impress on the disc a record of an image instead of a sound. By means of a suitable televisor this record can then be reproduced as a visual image. Also, we can at the same time record a sound or speech.

The problem of synchronising this speech and image in reproduction is very much assisted by all that has been done in solving the same kind of problem for the so-called " talking films " for the picture palace, so as to present not only moving representations of theatrical performances, but to enable the performers to be heard speaking as well.

It is not at all impossible that before very long we may be able to buy records which can reproduce on a gramophone and televisor screen not only the song of a singer but the sight of his or her face and smile as well.

There are also important possibilities connected with Mr. Baird's invention of " Noctovision," in which the invisible infra-red rays from a lamp are utilised for television and other purposes.

It is therefore a convenience to have set out, as Mr. Dinsdale has well done, the present state of these inventions, and to understand exactly where we stand in regard to their completion.

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Hence, this book may be recommended to those who desire an all-round view of the art of television as it exists at present, and of the problems and difficulties which still face the inventors in this novel field of adventure.

It should be added that this Foreword is written purely from a scientific point of view, and is not to be taken as expressing the writer's opinion that practical commercial achievement will necessarily follow on the lines above indicated.

J. A. F.

*July* 1928.

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# PREFACE TO SECOND EDITION

WHEN the first edition of this book appeared two years ago, it enjoyed the distinction of being the very first book to devote itself exclusively to the new science of television.

Since the first edition was published, however, so much work has been done on television, and such giant strides have been made in its development, both in this country and abroad, that it has been felt necessary to bring the book up-to-date.

The original work was written in a popular non-technical manner, with the object of interesting the man in the street, and giving him as clear an idea as possible what television actually is, the difficulties which have so long delayed its practical accomplishment, and the methods and apparatus which have been made use of by the various scientists who have interested themselves seriously in the subject.

It is felt that the first edition has achieved its object. Great interest is now being manifested in television, and many experi-



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menters have been attracted to this virgin field of scientific endeavour.

In revising the first edition, therefore, I have not only endeavoured to include an accurate account of the work which has been done during the past two years ; I have also made the entire book somewhat more technical, and enlarged it, with the object of making it useful to the amateur investigator as well as interesting to the average scientifically minded reader.

A. D.

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# TELEVISION

## CHAPTER I

### INTRODUCTION

WE of the present generation are living in a most marvellous age, but how many of us pause for a moment to dwell upon this fact? It is to be feared that very few of us do, for, together with its host of scientific marvels, this age, like all others, has its concomitant disadvantages. All is rush and hurry, a scramble for a mere existence, which wears away our energies and occupies our time to the almost total exclusion of all else.

The last thirty years have seen the growth and popularisation of a host of scientific wonders, outstanding examples of which are the cinematograph, the gramophone, the telephone, wireless telegraphy and telephony, the aeroplane, and the airship.

No one but a Jules Verne could have visualised, a hundred years ago, that to-day



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we would be able, by means of a simple instrument to be found in every business office and a very large number of homes, to converse freely with friends and business associates across both continents and oceans. Yet, to-day, this can be done with such ease that we accept the fact as part of our everyday lives, and think no more of it. The same applies to all our other marvellous modern inventions.

Fresh discoveries in the field of these inventions awaken but slight interest in us; they are being made every day with such frequency, and over such a wide range of endeavour, that we have neither the time nor the interest to follow them in detail.

The latest scientific marvel, television, has, however, succeeded in overcoming what might be described as our scientific indigestion and awakening keen interest, both in technical and in non-technical circles.

As there are still many persons who have but a hazy idea of what television really is, in spite of all that has been written about the subject recently, it may be as well at this point to define the word and describe its meaning.

The word " television " is derived from the Greek word *tele*, which means " at a distance," and the Latin verb *video*, " I see." Television literally means, therefore, " seeing at a dis-

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tance." It has been described also as "seeing by wireless," but as we may, by means of television, also see by wire, and as the basis in each case is a form of telegraphy, we might better describe television as "seeing at a distance by telegraphy."

In the interests of a pure language, philologists may not like the word "television," because it is derived from two different languages. But it has been coined, and is now in everyday use, so, we venture to think, it will continue to be used.

Television, in the stage of development which it has reached to date, may be described as a science or an art. Strictly speaking, however, although it may come to be recognised as such, it is not *a* science. It is a combination of practices known to several sciences and arts. Mechanics, optics, chemistry, electricity, and even wireless have all contributed their quota of knowledge, which, properly applied, has resulted in the achievement of television. It is but one more instance of the fact, rapidly being recognised, that the various branches of science are not so widely separated and independent as it was formerly customary to believe them to be.

When Graham Bell first discovered the telephone his fellow-scientists dubbed it an "interesting toy," and let it go at that. No one but the famous inventor himself was

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able to foresee the usefulness of his discovery and its enormous potentialities for service to mankind.

Such is the general lot of pioneers. Too often their work is not appreciated at its full value until they have long since departed from this world. In the case of the more fortunate, even they have to contend with public scepticism and apathy, and perhaps opposition, before the general public finally acquires a sufficient knowledge of the latest invention and its potentialities to accept and make use of it. Unless this happens within the lifetime of the inventor, there is no profit in the business of inventing—at least, not for him.

Let us consider for a moment, therefore, the significance and potential usefulness of television. Granted that we can see what is happening at a distance, instantaneously, as it happens, how can we make practical use of this ability?

One of the most vital factors in the progress of the human race, from the beginning of time, has been communication. It is of the utmost importance to us that we should be able to establish communication with our fellow-men, and one of the earliest methods of doing so, and still the most effective, is by word of mouth.

It is not by word of mouth only that we

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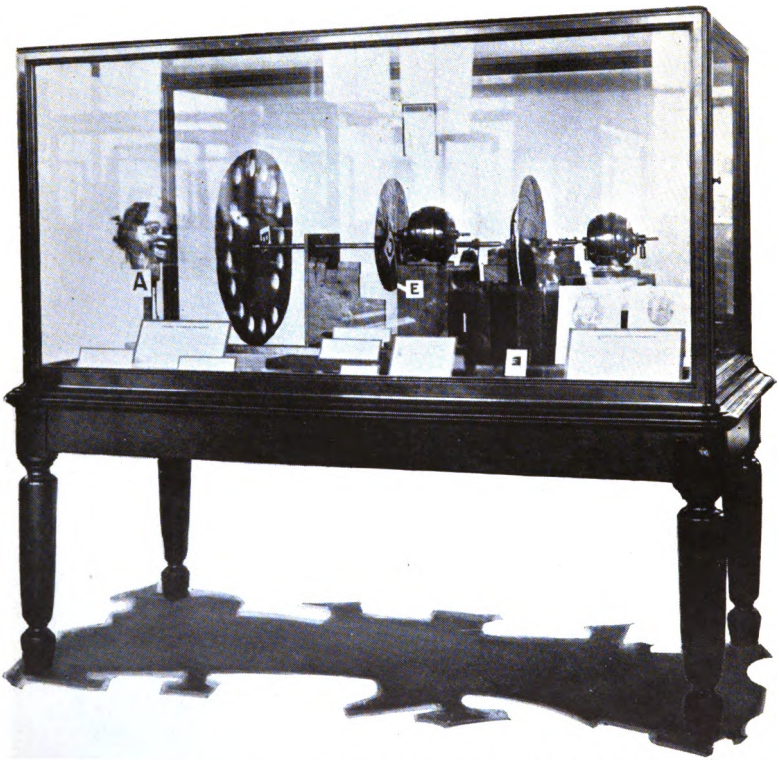


J. L. BAIRD'S ORIGINAL TRANSMITTER, BY MEANS OF WHICH HE FIRST ACHIEVED REAL TELEVISION.

The apparatus is on view at the Science Museum, South Kensington. (For description see pages 73–76.)



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communicate with our fellow-men, however. It is not generally realised what a great part is played in oral communication by facial expression. Shut your eyes, or talk to a man in pitch darkness, and the intelligence conveyed by facial expression will soon be missed.

Consider the telephone. Apart from the physical deficiencies of the instrument, it is surprising how often failure fully to grasp the distant speaker's import is due to our inability to *see* him. Thus, when we endeavour to receive a communication by telephone, we have to rely upon but one of our senses, that of hearing.

Similarly, take the "gags" of certain comedians. The actual words they use, when set down in cold type, appear to be as flat as the proverbial pancake. But when they "put them over" the footlights, simultaneously with appropriate facial expressions, they produce roars of laughter amongst the audience.

So potent is facial expression, in fact, that it is quite possible to produce roars of laughter without saying a word. This is demonstrated daily in every cinema, where amusement, drama, and education are conveyed to the audience by appeal to one sense only, that of sight.

In the fields of radio broadcasting and

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gramophone entertainment we revert to conditions similar to those under which we labour when conducting a telephone conversation. We hear what is going on in the broadcasting studio or what has been impressed on the record, as the case may be, but the visualisation of the scene in the studio has to be left to our imagination. For this reason there are a large number of music lovers who would far rather go personally to a musical performance than listen to a reproduction of it by the most perfect of radio receivers or gramophones.

It is evident, therefore, that when it comes to communicating human intelligence over a distance, sight is as important a factor as hearing, if not more so.

There is surely an important application in the field of communication, therefore, for any device which will reinforce our receptive powers by enabling us to utilise the sense of sight as well as that of hearing, when we endeavour to communicate over great distances.

That is the future position of television in the scheme of human affairs.

By means of it we shall one day be able to see as well as hear the man at the other end of the telephone line. We shall be able to see as well as hear what is going on in the studio of the broadcasting station; and

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instead of waiting for a verbal description in the newspapers of events of national importance, or listening to the sounds of it as broadcast, we shall be able actually to see a reproduction of the event on a screen as and while it is actually taking place.

For many years inventors in many lands have been striving to accomplish these things. In the succeeding chapters we shall see something of the many methods which have been tried, and just how much success has been achieved.

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## CHAPTER II

### THE SELENIUM CELL. THE HUMAN TELEVISION SYSTEM. THE EXPERIMENTS OF RIGNOUX, FOURNIER, AND RUHMER

AS was explained in the last chapter, "television" means seeing what is happening at a distance while it is actually happening.

Over short distances, provided no other objects intervene, this is done daily with the naked eye. Over greater distances it is possible to see what is happening with the aid of a pair of binoculars or a telescope, But no human eyesight, even with the assistance of binoculars or telescope, will enable us to see through brick walls, or from our armchair at home to see the Prime Minister speaking in the House of Commons.

We can, of course, see a photograph afterwards of the Prime Minister in the act of speaking; and if this photograph were to be transmitted to us by wireless or land-line telegraphy, instead of being sent through the post, this would be "phototelegraphy." It is not television.



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A TYPICAL PHOTOELECTRIC CELL.



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As the word itself suggests, phototelegraphy concerns itself solely with the transmission by telegraphy of "still" pictures, and may be said to bear the same relationship to television as the magic-lantern does to the cinematograph.

Novelists have had no doubt as to the meaning of "television." In countless books the miracle of seeing what is actually happening elsewhere is treated as an accomplished fact, and embodied in the story. Actually, it is only very recently that the miracle has been achieved.

The history of television forms one of the romances of modern science, and it may be said to date from the discovery of the light-sensitive properties of selenium.

Before these properties were known, selenium was used in telegraphy to provide the high resistances necessary, for selenium, unlike most other metals, offers an enormous resistance to a current of electricity. It was this property which led to its use in the Atlantic cable-receiving station in the village of Valentia, on the south-west coast of Ireland.

It so happened that one afternoon sixty years ago (in 1873, to be precise) the operator, a Mr. May, noticed that his instruments were behaving in a strangely erratic fashion. It was a day of brilliant sunlight, and the sun's

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rays, shining through the window, occasionally shone upon the selenium resistances. Every time this happened, Mr. May noticed that the needle of his instrument moved.

The light-sensitive properties of selenium were thus discovered accidentally by an obscure telegraph operator, and when the discovery was communicated to the scientists of the day it created widespread interest. It opened up enormous possibilities by giving a means of turning light into electricity, and many scientists were quick to predict that selenium would provide an electric eye to supplement the electric ear which the then recently invented telephone had just given to them.

There was, however, a serious difficulty to be overcome, and over fifty years had to elapse before the solution was found. This was the difficulty: Whereas the human eye sees a whole scene in a single comprehensive glance, it is not possible for selenium to achieve the same result.

Perhaps the simplest way to make the matter clear is to consider that very perfect television apparatus, the human eye, with its connecting nervous system. A section of the eye is shown in Fig. 1.

The eye itself may be compared to a camera. It has a lens and a screen, the lens throwing upon the screen an image of the scene

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before the eye. This image has to be conveyed to the brain, and Nature's method of solving her television problem has formed the basis of many of the first television schemes.

When the human screen (which is called the retina) is closely examined, its surface is found to consist of a mosaic made up of an

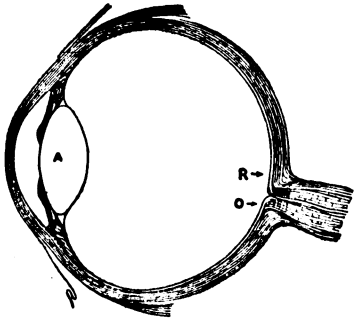


FIG. 1.—A SECTION OF THE HUMAN EYE—NATURE'S TELEVISION APPARATUS.

The lens A projects an image of the scene on to the retina, R, the cells of which convert light into impulses, which are conveyed to the brain by the nerve channels, O.

enormous number of hexagonal cells. Each of these cells is directly connected to the brain by a number of nerve filaments, along which travel impulses the intensity of which is dependent upon the intensity of the light falling upon each hexagonal cell.

Exactly how these impulses are generated is not at present fully understood, but they

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are almost certainly due to the presence of a light-sensitive substance, known as visual purple, which constantly flows through the hexagonal cells.

The images which we see are thus built up of an extremely fine mosaic of microscopic hexagons of varying degrees of light and shade. The number of these cells is stupendous, there being several millions in the normal human eye.

The early television experimenters endeavoured to construct artificial eyes by substituting selenium for visual purple and building an artificial retina out of a mosaic of selenium cells, each of these cells being connected by wires to a shutter.

For every selenium cell used there was a shutter, and each shutter was arranged to open when light fell upon the particular cell connected to it. As each shutter opened it allowed a spot of light to fall upon a screen at the receiving end of the circuit. In this way each selenium cell controlled a spot of light, the image being produced by a mosaic formed of these spots.

Apparatus modelled on these lines was actually made by several inventors. Rignoux and Fournier, two French scientists, constructed such a machine in 1906. This apparatus was intended only to demonstrate the principle, and had no pretensions towards

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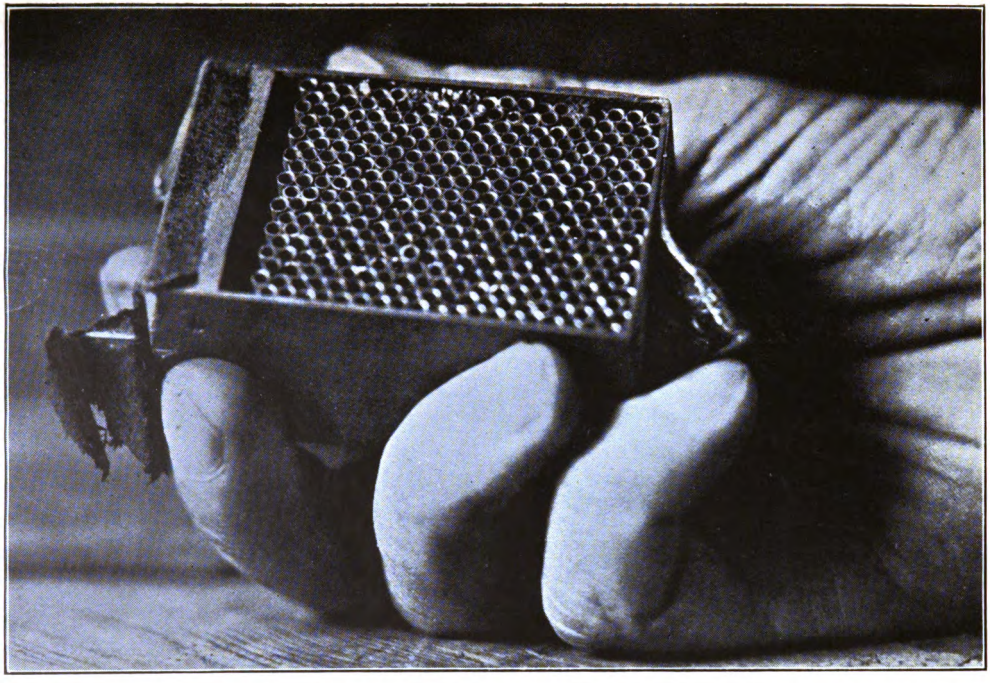

THE HONEYCOMB STRUCTURE.

Devised by Baird during the course of some early attempts to refine the grain of the television image, as described on page 78.



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being an instrument for the actual accomplishment of television.

The transmitter consisted of a wall covered with selenium cells, sixty-four fairly large cells being used. From each of these cells two wires ran to the receiving screen, which was made up of sixty-four shutters, each shutter being controlled from its respective selenium cell. Thus, when any given cell at the transmitting station was brilliantly illuminated, it sent a strong current over the two connecting wires to the receiving station, where it caused the appropriate shutter to open so that light could shine through on to the corresponding part of the receiving screen. By covering the transmitting wall with large stencils, images of letters of the alphabet were transmitted and could be recognised at the receiver.

Ernest Ruhmer, whose brilliant pioneer work in connection with wireless telephony is so well known, also constructed a similar apparatus, and many other workers have been attracted to this system. However, the thousands of cells, shutters, and wires necessary made the practical adaptation of such schemes entirely out of the question, and an endeavour was made to solve the problem in quite a different manner.

The suggested alternative was to divide the scene up into a great number of small parts

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and then transmit it section by section to the receiving end, where the scene was to be reassembled again like the pieces of a jig-saw puzzle. The entire operation was to be carried out so rapidly that the effect upon the observer would be the same as that of an instantaneous glance by direct vision.

Imagine, for example, that by means of a lens an image of the object or scene to be transmitted were to be thrown upon a ground-glass screen, just like the focusing screen of a camera. Imagine this image divided up into thousands of little squares like a chess-board, each one of these little squares being dark or light, depending on what part of the picture it belongs to.

Now we have to send this picture over a wire or wireless circuit. For the sake of an example, let us assume that there are 1,000 squares numbered 1, 2, 3, 4, 5, 6, 7, etc., up to 1,000; then if we send a series of messages, 1 dark, 2 light, 3 light, 4 dark, etc., to an assistant at the receiver who has before him a board divided also into 1,000 squares, and if he makes his squares light or dark as directed, he will build up a mosaic similar in all respects to that on the ground-glass screen at the transmitting end.

Now, in this operation, we looked at each little square at the transmitting end, and our eye told us whether it was dark or light. If,

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instead of using our eyes, we passed a light-sensitive cell over the squares, it would send out a series of electrical impulses which would be strong or weak in accordance with the lightness or darkness of the squares.

If, at the receiving station, we had, instead of a human assistant, a mechanical device which would direct a narrow beam of light from a lamp on to each square of the receiving board in turn, at exactly the same time as the cell at the transmitting station passed over the corresponding square on the ground-glass screen; and if, further, the intensity of the light was arranged to be controlled by the varying current from the cell, then each square of the board at the receiver would in turn be illuminated with a brightness corresponding to the brightness of the same square on the transmitting screen.

If this entire operation were to be carried out at least eight times per second, then the observer would see on the receiving board, not a moving light-spot of varying intensity, but the whole image at once, giving the effect of an instantaneous glance.

The fact that the moving light-spot is not visible as such is due to the phenomenon known as retentivity of vision, whereby an image, once impressed upon the retina of the eye, takes an appreciable interval of time to fade. Thus, at the cinema, what we actually

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see is sixteen complete pictures per second, but retentivity of vision deludes us into believing that what we actually see is a single smoothly flowing picture.

Upon the principle described above, a great number of television devices have been evolved, and it is to development along this line of research that success was ultimately due.

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## CHAPTER III

### VARIOUS ATTEMPTS TO SOLVE THE PROBLEM. SZCZEPANIK, ROSING, MIHALY

IT is not necessary to weary the reader with detailed descriptions of all the apparatus which has been devised from time to time for the accomplishment of television. It is only necessary here to give the details of a few of the machines developed by the earlier workers, in order to convey a general idea of the methods which have been tried. In succeeding chapters we will go further into the details of apparatus of more modern design which has actually proved successful in operation.

It is, however, necessary to pay tribute to the efforts of the early workers, who, although unable themselves to achieve success, laid the foundations upon which, later on, the inventive genius of their successors was to build.

Fig. 2 illustrates one of the most representative and suggestive of the early television schemes, due to Jan van Szczepanik.



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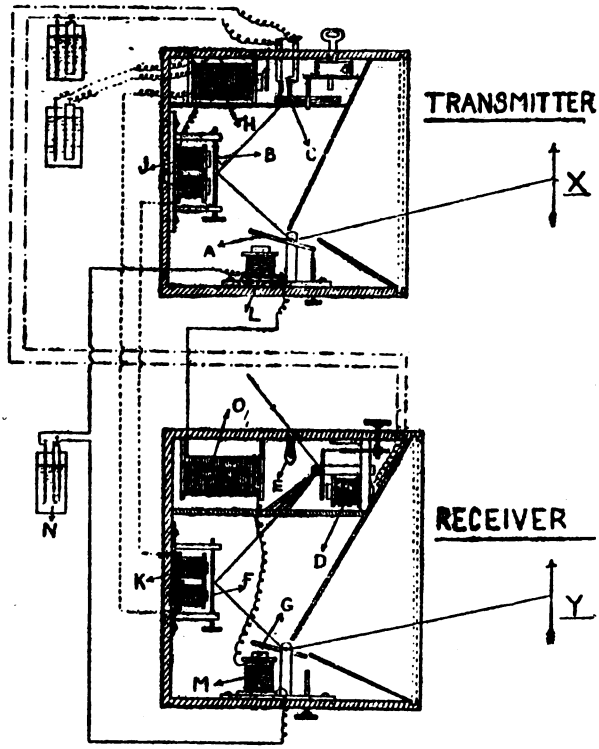


FIG. 2.—SZCZEPANIK'S TELEVISION APPARATUS.

X = Object to be transmitted. A = First vibrating mirror. B = Second vibrating mirror. C = Selenium cell. D = Magnet controlling light spot. E = Source of light. F = Vibrating mirror. G = Vibrating mirror. H = Synchronising coil supplying alternating current to J and K. J = Magnet controlling B. K = Magnet controlling F. L = Magnet controlling A. M = Magnet controlling G. O = Synchronising coil supplying alternating current to L and M. Y = Received image.



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Referring to the diagram, the light reflected from the object to be transmitted, X, is focused by means of a lens firstly on to the mirror, A, which is maintained in a state of rapid vibration by the electromagnet, L. From A the beam of reflected light is reflected again on to the mirror B, which is kept vibrating at a much slower rate by the electromagnet, J. This second mirror vibrates at right angles to the first one. The combined action of these two mirrors causes the beam of light containing the image to traverse the aperture of the light-sensitive cell, C, in a zig-zag path.

In order to make the action clear, let us consider the action of the camera. If the lens is opened, and a ground-glass screen put in position instead of the sensitive plate, an image of the scene before the camera appears on the screen.

In the television transmitter, an image of the scene, X, appears in exactly the same manner on the first mirror, A.

The combined action of the two vibrating mirrors is the same as if we could, in some way, take the focusing screen of the camera, with the image of the scene still showing on it, and rapidly move it to and fro in a zig-zag path across the aperture of the light-sensitive cell, C. If we did this, it is clear that eventually the aperture of the light-sensitive cell would

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have looked at, or scanned, the entire surface of the ground-glass screen. That is to say, it would have scanned the entire image visible thereon, and been influenced by the degree of lightness or darkness of parts of the image which passed it.

At the receiver the operation is exactly similar to that of the transmitter, only the light-sensitive cell is replaced by the light, E. A beam from this lamp is first focused on to a vibrating mirror which is controlled by the magnet, D, which, in turn, takes its supply current from the electrical impulses sent to the receiver by the light-sensitive cell at the transmitter.

Thus, the intensity of the light reflected from this first mirror depends upon the deflection of the armature, and this deflection, as explained above, depends upon the strength of the current arriving from the transmitter.

This varying light beam is then reflected on to the vibrating mirror, F, and from thence to the third vibrating mirror, G. As in the case of the transmitter, these two latter mirrors vibrate at right angles, thus giving to the light beam a double movement; one a rapid to-and-fro motion, imparted by the more rapidly vibrating mirror; the other a more gradual movement downwards, imparted by the mirror which vibrates at the slower speed.

The resultant action of the apparatus is

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[*Photo courtesy General Electric Co., U.S.A.*

ANOTHER FORM OF PHOTOELECTRIC CELL.



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that the beam of light is spread over the screen, Y, moving rapidly to and fro across it, and slowly down from top to bottom. Since the light beam is varying in intensity, due to the action of magnet, D, it follows that the intensity of illumination of different parts of the screen will be different, corresponding exactly with the light and shade of the scene at the transmitter. The entire action takes place so rapidly that, to the eye of an observer, the screen appears to be continuously illuminated with the image being received.

That is the general arrangement of Szczepanik's apparatus, but successful results were never achieved with it. Two insuperable obstacles to success remained. One of these was that a suitable light-sensitive device was not available; the other was the difficulty of synchronism, i.e. arranging for the mirrors at both transmitter and receiver to vibrate exactly in synchronism, or in step with each other. Unless the mirror systems at both ends of the circuit operate at exactly the same speed, successful results cannot be obtained, for the received picture becomes hopelessly muddled up.

Another device of a more interesting character is that suggested in 1907 by Boris Rosing, a Russian Professor. His transmitting arrangement was similar in many respects to others, but his receiving device

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was very original, in that it dispensed altogether with mechanical parts, and used, instead, a cathode-ray tube.

Prior to the publication of Rosing's arrangement, Mr. A. A. Campbell Swinton had suggested the use of the cathode ray both for the transmitter and the receiver.

The cathode ray is a form of electrical discharge which occurs when electricity at very high potential is forced through a very high vacuum. The rays can be produced in the form of a thin pencil-like stream, and if directed on to a special form of fluorescent screen, they can be rendered visible.

Cathode rays have the important characteristic (from a television standpoint) that they are capable of being moved, or diverted from their path, in any direction, either magnetically or electrically. The rays have no weight, and therefore no inertia, and there is thus no limit to the speed at which they can be caused to move about.

When the rays strike a plate of fluorescent material, a brilliant spot of light is produced, so that by using cathode rays in conjunction with a fluorescent screen, we get a receiving device which is capable of responding at practically any speed.

Rosing's arrangement is shown in Fig. 3. At his transmitter he used two mirror polyhedrons revolving at right angles to

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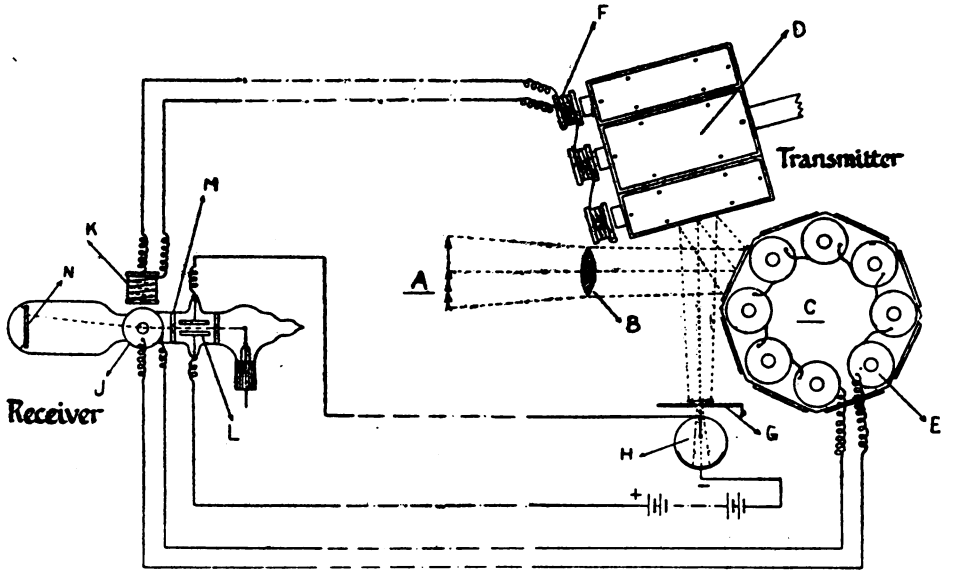


FIG. 3.—ROSING'S TELEVISION APPARATUS.

A = Object to be transmitted. B = Lens. C = Mirror polyhedron with magnets attached. D = Ditto. E = Stationary coils generating alternating current. F = Ditto. G = Diaphragm with aperture admitting light to H. H = Photoelectric cell. K = Magnet coil giving vertical deflections to cathode ray. J = Magnet coil giving lateral deflections to cathode ray. L = Plates, the varying potential of which is controlled by H and deflects the ray away from the aperture in the diaphragm M. N = Fluorescent receiving screen.

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each other. These are shown in the diagram at D and C.

The combined motion of these mirrors caused an image of the object to be transmitted, A (focused on to C through the lens, B) to be swept across the aperture of the photoelectric cell, H. The action of the image-scanning mechanism was in all respects similar to the one previously described in connection with Szczepanik's apparatus.

The varying current impulses from the cell, H, were transmitted to the receiver, where they were caused to charge two condenser plates, L, in the cathode-ray tube. The fluctuating charge impressed on these condenser plates caused the cathode ray to be deflected away from the aperture, M, placed in its path, and the amount of the ray which passed through the aperture was thus made proportional to the potential of the plates, i.e. to the degree of light and shade in the original scene.

Having got through the aperture, M, the ray then struck the fluorescent screen, N. The manner in which the ray was caused to bend to and fro, thus covering the entire screen, was quite ingenious.

The revolving mirror polyhedrons carried magnets which revolved with them. These magnets acted upon groups of fixed coils, set close to the polyhedrons, setting up alternating currents in them. Two alternating

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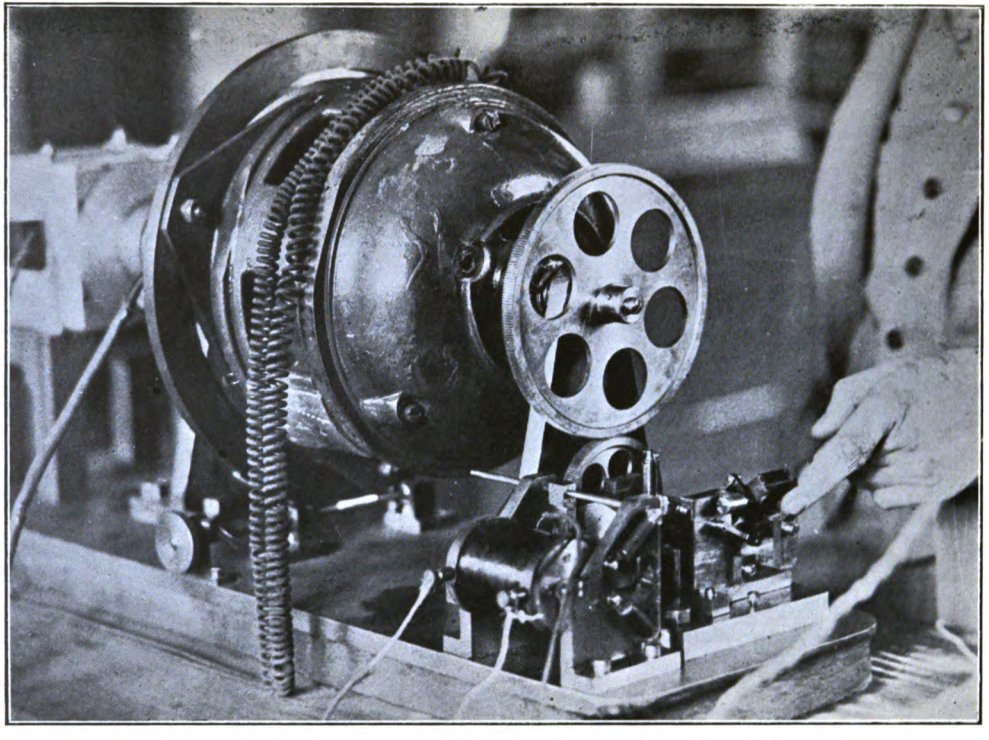

A CLOSE-UP VIEW OF THE BELIN APPARATUS.

Finger is pointing to the tiny vibrating mirrors. The apparatus is described in Chapter V.



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currents were generated in this way, one of them by one revolving polyhedron, and the other by the second polyhedron. Both currents were sent along separate pairs of wires to the receiver, where they were arranged to energise two electromagnets, K and J, one of which gave to the cathode ray vertical movement, while the other gave to it horizontal motion.

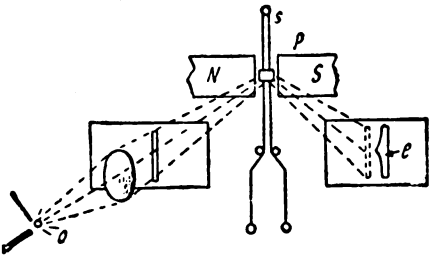


FIG. 4.—DETAILS OF MIHALY'S OSCILLOGRAPH.

In more recent years Denoys von Mihaly, of Vienna, has been experimenting with an apparatus which, although very complex, is nevertheless of interest.

The principal feature of this apparatus is the image-scanning mechanism. This takes the form of a system of very small oscillating mirrors, having an area of one square millimetre, or less. The arrangement is shown in detail in Fig. 4, where the mirror, P, is fixed to a loop of extremely fine platinum wire, S.

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The diameter of this supporting wire is of the order of ·01 mm., and it is stretched between the poles of a powerful electromagnet, NS. This arrangement is a form of the well-known Siemens oscillograph.

The transmitting apparatus is shown in Fig. 5. The lenses A and B reduce in area the

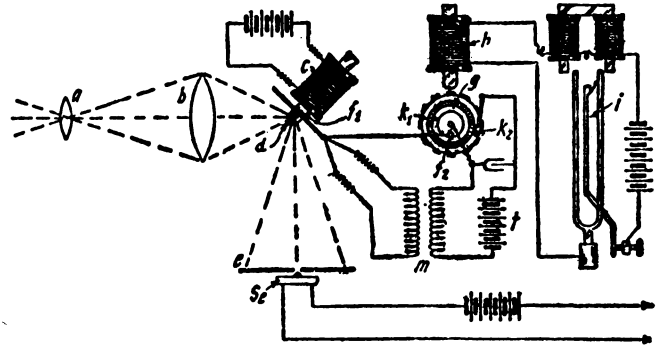


FIG. 5.—MIHALY'S TRANSMITTING APPARATUS.
The object to be seen at the receiver is placed in front of the lens, *a*.

image of the picture which is to be transmitted, and project it on to the small oscillograph mirror, D. This mirror oscillates at a frequency of 500 vibrations per second, and is set in oscillation at this speed by means of a 500-cycle alternating current which is caused to flow through the fine platinum suspension wire.

The same mirror also vibrates at a much

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slower frequency in a plane at right angles to that of the 500-cycle oscillation, the slower vibration being imparted to it by means of the lever connecting it to the phonic wheel, G. This wheel, or drum, is driven by the electromagnet, H, which, in turn, receives its alternating current supply from the tuning fork, I. This tuning fork vibrates at a frequency of 100 per second, and the drum, G, which it is responsible for driving, rotates at a speed of 300 revolutions per minute.

The revolving drum and tuning fork form part of the synchronising apparatus, further details of which will be given in the chapter devoted to synchronism.

The manner in which the image of the scene to be transmitted is broken up into its component picture elements is as follows. The reduced image projected on to the oscillating mirror is reflected therefrom on to the screen, E. This reflection is approximately the same size as the original image, on account of the "swing," or divergence of the light rays which results from the oscillations of the mirror.

In the middle of the screen, E, there is an aperture approximately one millimetre wide, which runs the full length of the screen, or diaphragm. Behind this aperture is placed, in the Mihaly apparatus, a selenium cell, and the action of the mirror causes the complete

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image of the scene to traverse the cell in one-tenth of a second.

As already stated, the drum, revolving at 300 revolutions per minute, oscillates the mirror in one plane, i.e. at the rate of 5 vibrations per second. It is oscillating in a plane at right angles to this motion at 500 vibrations per second.

Therefore, in one-tenth of a second, while the mirror makes 50 oscillations in a vertical plane, half an oscillation is made in a horizontal plane. This means that the image is swept across the aperture leading to the selenium cell in 50 horizontal lines, which are drawn across the screen, E, one below the other. The 1-millimetre aperture in the screen ensures that each line, instead of striking the selenium cell all at once, does so from one end to the other, in 1-millimetre graduations.

The current from the selenium cell, S*e*, is amplified and sent to the receiving station.

The receiving equipment, shown in Fig. 6, is somewhat similar in arrangement to the transmitter. The same forms of tuning-fork, I, phonic drum, G, and oscillograph mirror, D, are used. Instead of a selenium cell, there is in the receiver a so-called "light relay," which is the device which converts the incoming picture current fluctuations into light fluctuations, which are spread over the receiving screen, T.

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The light relay consists of a very sensitive bifilar oscillograph of special design. The arc lamp, O, through a system of lenses, projects a narrow but extremely intense beam of light on to the mirror, P, of the oscillograph. The fluctuating picture current from

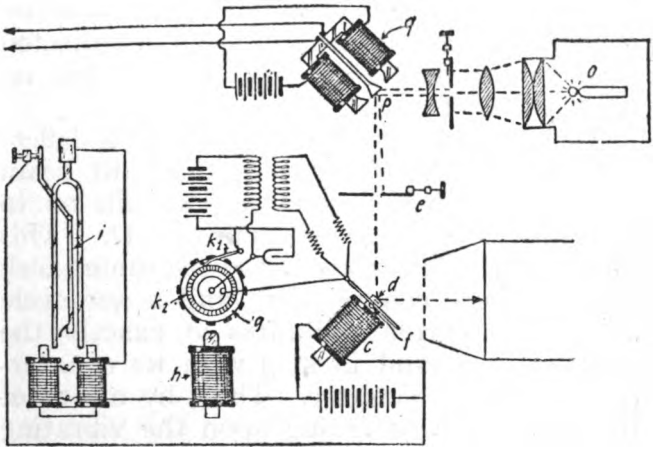


FIG. 6.—MIHALY'S RECEIVING APPARATUS.

the transmitter is conducted through the fine wire supporting the mirror, and as this wire is in the field of the electromagnet, Q, the mirror is deflected in direct proportion to the strength of the current flowing through its supporting wire.

This deflection causes more or less of the light beam to fall on the aperture, E, all the

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beam passing through it when the received current is strong (indicating a brilliantly illuminated section of the scene at the transmitter), and only a very small portion of it, or none at all, when the received current is weak, or nil.

When no current is passing through the suspension loop of mirror, P, the narrow beam of light reflected from the mirror is projected close to the diaphragm aperture, E, but no light passes through it.

As soon as a current flows, causing a deflection of the mirror, some of the light beam passes through the aperture and falls on to the second oscillograph mirror, D. This mirror, through the agency of the tuning fork phonic wheel combination, and a 500-cycle alternating current, vibrates in exactly the same manner, and in step with its counterpart at the transmitter. Thus, by means of the reflected light falling upon the vibrating mirror and being reflected on to the screen, T, the picture is reproduced.

In spite of the ingenuity of the above arrangement, television could not be achieved, due, partly, to the unsuitability of the selenium cell as a means of converting light into electricity; but principally to the fact that the optical system is incorrect. Mihaly describes his oscillograph mirror as being "a thin flat mirror." Referring to Fig. 4,

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if the mirror, D, has a plane surface, no image will be reflected on to the screen, E, but only a blur.

The difficulty of the light-sensitive device has been the stumbling block over which, until recently, all television experimenters have tripped, and in the next chapter we shall devote some space to a consideration of light-sensitive devices in general.

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# CHAPTER IV

## LIGHT-SENSITIVE DEVICES

IT will be interesting, at this stage, to consider the principal barrier which has prevented so many television schemes from achieving success. The vast amount of research work which has been done in this field can only be appreciated by those who have made an intimate study of the subject; and it seems at first sight strange that a problem which, on paper, appears to be comparatively simple, should have proved so infinitely baffling in practice.

We have seen, in the preceding chapters, that one of the most vital factors in all television schemes is the light-sensitive cell, whose duty it is to transform light impulses into electrical impulses.

All light-sensitive devices depend for their action upon what is known as the "photo-electric phenomenon." This phenomenon has been subdivided into two distinct types, photo-conductivity and photo-emissivity.

The first of these was originally discovered,



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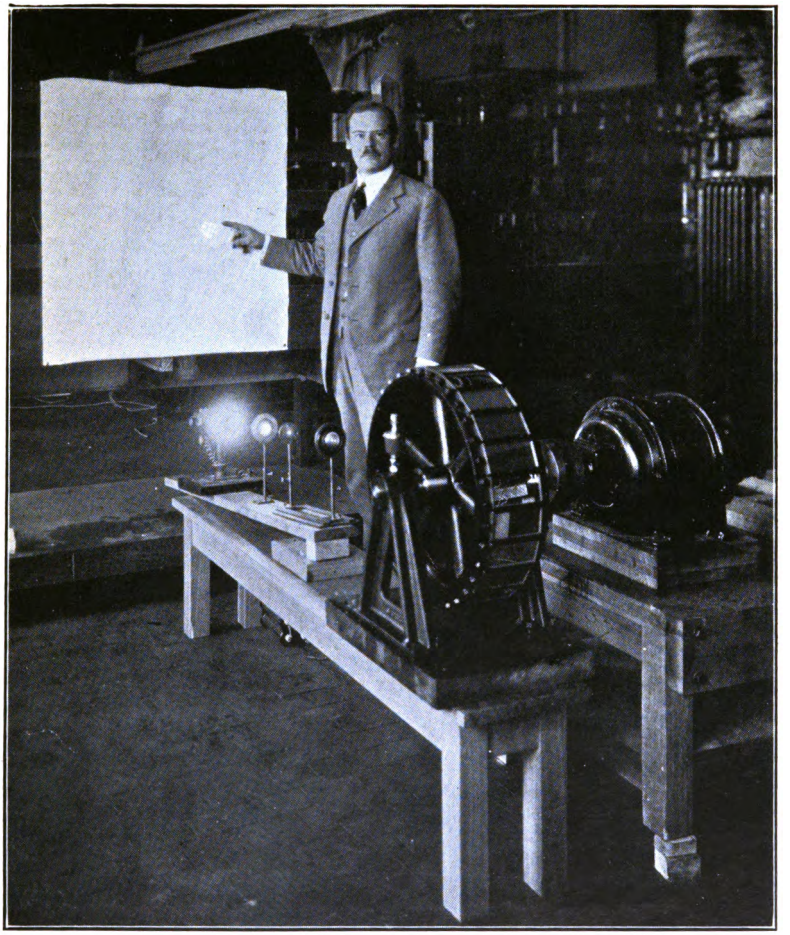

[*Photo courtesy General Electric Co., U.S.A.*

DR. ALEXANDERSON, OF THE GENERAL ELECTRIC CO. (U.S.A.), POINTING TO THE SEVEN LIGHT SPOTS THROWN ON THE SCREEN BY THE SEVEN-SPOT PROJECTOR REFERRED TO ON PAGE 109.



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as described in Chapter II, by a telegraph operator, who noticed that when sunlight fell on some resistances made of the metal selenium, the needle of his instrument moved.

This discovery led to a detailed investigation of the phenomenon by the leading scientists of the day, notably Willoughby Smith, with the result that the fact was established that so long as selenium is kept in darkness its resistance to electricity is extremely high. As soon as it is exposed to light, however, its resistance drops very considerably.

This fact established, efforts were immediately made to make use of selenium as a means of transforming light into electricity, and for this purpose special devices, known as selenium cells, were constructed, the usual method of manufacture being as follows.

Two wires, spaced about ·5 mm. apart, are wound simultaneously over a flat piece of insulating material. These wires do not make contact with each other at any point. A coating of amorphous selenium is then spread over the wires, filling the spaces between them, and a heat treatment is then applied which has the effect of turning the selenium into the grey crystalline form which has been found to be most sensitive to light variations.

The method of construction is shown in Fig. 7.



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An average cell made up in this manner has an electrical resistance (between the ends of the two wires over and between which the selenium is spread and baked) of between 60,000 and 100,000 ohms. By illuminating the cell with a 16-c.p. incandescent lamp placed at a distance of 1 metre, its resistance drops to approximately 30,000 or 40,000 ohms,

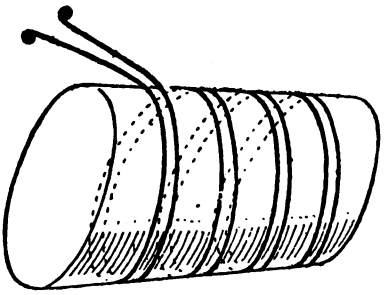

FIG. 7.—SHOWING THE CONSTRUCTION OF A SIMPLE FORM OF SELENIUM CELL.

or about half the resistance of the cell when it is in darkness.

The theory of the action of a selenium cell, or any other cell belonging to the photo-conductivity class, is that electrons are liberated from the molecules within the substance by the action of light, and these electrons are recombined again when the cell is no longer exposed to light. These processes, especially that of recombination, take a

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certain definite time to occur, thus giving rise to the well-known time-lag of the selenium cell.

It is this time-lag which makes the selenium cell totally unsuitable for television purposes, for in television, a light-sensitive device is required which will respond instantaneously to the light impulses which fall upon it. As will be seen later, these impulses fall on the cell at the rate of many thousands per second, and such speeds are hopelessly beyond the ability of selenium to respond to.

Apart from selenium, a number of other metals exhibit the property of photo-conductivity, notably thalium sulphide, which is the substance used in the "Thalofide" cell. This is similar in its properties to the selenium cell, but is said to be more constant and reliable in operation.

The phenomenon of photo-emissivity was first discovered in 1888 by Hertz, who found that when light fell upon a spark gap the electric discharge passed more readily, i.e. the resistance of the gap was reduced. This effect was investigated by another German scientist named Hallwach, who discovered that the effect was located at the negative pole of the spark gap.

Further investigations by subsequent workers disclosed the fact that all metals, under the influence of light, emit electrons, but the effect is more pronounced in the case of

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metals belonging to the so-called alkali group, such as rubidium, potassium, and sodium.

By making use of this effect a new type of light-sensitive cell, known as the photo-electric cell, was developed. This type of cell consists essentially of a plate of one of the three metals mentioned above, enclosed in a high vacuum and connected to the negative pole of a battery or other source of high negative potential. This plate forms the cathode of the cell, the anode consisting of a loop of wire or wire gauze facing the cathode.

The potential used to operate the cell is usually of the order of 200 volts. In some cases, where the containing bulb of the cell is filled with a gas at low pressure, the potential used should not be great enough to cause a glow discharge. In the case of a cell filled with neon gas, this optimum potential is of the order of about 175 volts.

Besides neon, helium has also been used, and a rubidium cell in an atmosphere of helium is a common combination. Potassium and helium is also a popular arrangement, and gives one of the most sensitive forms of cell.

A common circuit arrangement for use in conjunction with a photoelectric cell is given in Fig. 8.

Photoelectric cells are chiefly sensitive to light rays belonging to the violet end of the spectrum, and are almost totally insensitive

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[*Photo courtesy Westinghouse Electric Co., U.S.A.*

V. K. ZWORYKIN, OF THE WESTINGHOUSE ELECTRIC CO., WITH HIS COMBINED PHOTOELECTRIC CELL (upper part) AND THERMIONIC VALVE (lower part).



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to red or other rays at the lower end of the spectrum.

Selenium cells, on the other hand, are very responsive to red rays, and insensitive to rays belonging to the upper end of the spectrum.

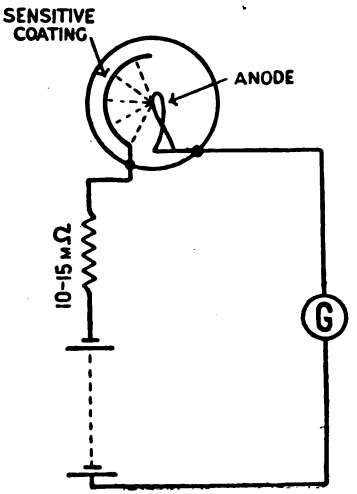


FIG. 8.—CIRCUIT DIAGRAM OF A PHOTOELECTRIC CELL AND ASSOCIATED EXTERNAL CIRCUIT.

When light falls on the cell a current flow will be indicated by the sensitive galvo, G.

The selenium cell gives a vastly greater current output under the influence of light than any form of photoelectric cell. Whereas the latter, when illuminated, will give a current of only a few microamperes, the ordinary selenium cell will give a current

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which can be measured in milliamperes. Special large selenium cells have actually been constructed which will pass a current of 1 ampere, such enormous cells being used in the Cox Selenium Relay, employed in cable work.

Photoelectric cells, as already mentioned, depend for their action upon photo-emissivity. That is to say, under the action of light the cathode emits electrons. Since the velocity of electrons is of the same order as that of light, i.e. about 186,000 miles per second, it follows that the response of the photoelectric cell will be, to all intents and purposes, instantaneous. This proves to be the case, so that it would appear, at first glance, that the ideal light-sensitive cell for television purposes is ready to hand, and many workers seized upon it with avidity as a solution to their difficulties in connection with light-sensitive devices.

They were doomed to disappointment, however, for, as previously stated, the output of a photoelectric cell is of the order to a few microamperes only. Attempts have been made to amplify the output to the required extent by means of thermionic valve amplifiers, but the degree of amplification necessary to achieve results in television is so great that even modern amplifiers cannot satisfactorily attain it.

Valve amplification can only be pushed to a certain limit, beyond which difficulties

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appear in the shape of parasitic noises due to battery irregularities, irregularities in electron emission from valve filaments, etc. These parasitic irregularities, which can be heard as noises if listened to, take the visible form, in television, of white spots, lines, and bars, occurring with such frequency on the receiving screen as to mar or totally obscure the received image.

In an effort to overcome the low output handicap of the photoelectric cell, V. K. Zworykin, of the Research Department of the Westinghouse Electric Co., devised an interesting form of cell which incorporates within the same glass bulb the elements of a three-electrode valve.

The lower portion of the bulb contains the valve elements, whilst the upper half, which is screened from the valve portion by a light-tight partition, contains the photoelectric cell. The light-sensitive substance used in the cell is potassium hydroxide, and this is spread in the form of a coating over one inner side of the upper part of the glass bulb.

The valve filament is of the oxide-coated variety, which operates without perceptible glow. By using such a filament, no unwanted light from this source can reach the light-sensitive coating of the cell.

With this arrangement, using a hard valve, Zworykin claims to be able to obtain an out-

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put of 1 milliampere. For higher outputs a type of 4-electrode valve is used, using the first grid as an anode with a low potential of the order of about 30 volts positive. The second grid is connected in orthodox fashion, and the plate has a positive potential of the order of 150 volts impressed upon it. By a proper choice of spacing between electrodes, and grid mesh, it is possible to obtain a good relationship between the degree of illumination and current output within certain limits.

It is claimed that a continuous current output of 5 milliamperes has been obtained with the 4-electrode valve combination, the limiting factor being the heat developed within the photoelectric cell. Since alkali metals are highly volatile, overheating of the cell causes distillation of the metallic coating, which condenses upon the transparent glass and insulating parts. It was stated, however, when this development was first made public, that this difficulty can be remedied to a great extent by improved construction.

Other devices which might be classed as light-sensitive devices are the bolometer and the thermopile. These are not sensitive to light, as such, but register any rise in temperature due to it; and light, such as sunlight, may be detected by the rise in temperature caused when it falls upon such instruments.

The bolometer consists essentially of a strip

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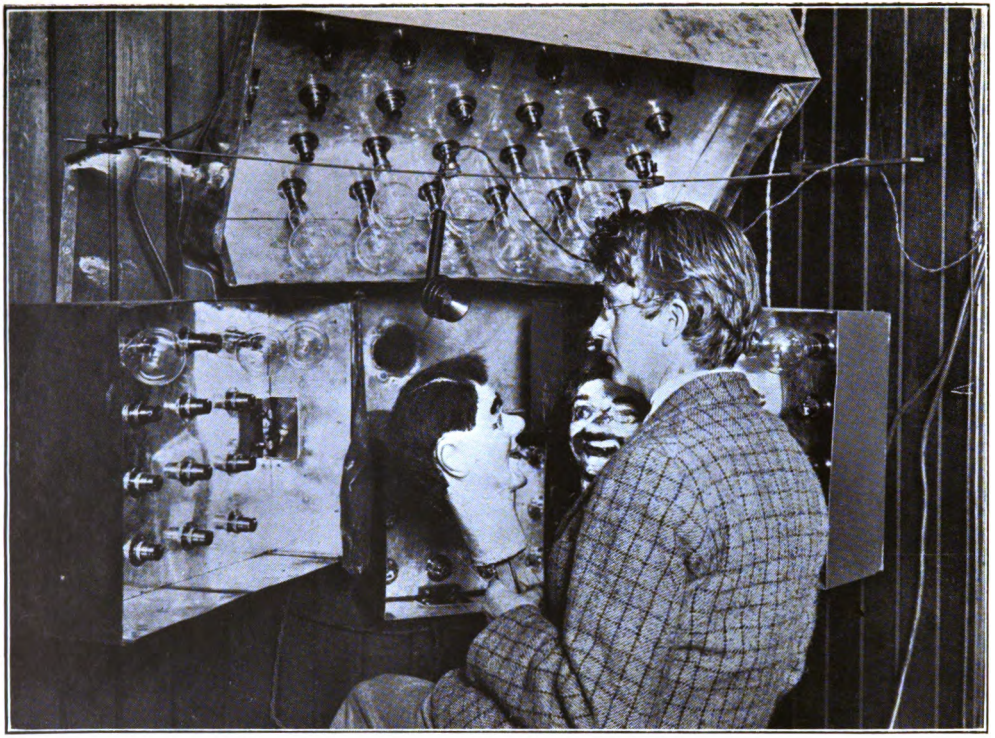

MR. BAIRD SEATED BEFORE ONE OF HIS EARLY TRANSMITTERS.
Note the powerful illumination required, which is referred to on page 146.



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of very thin metal foil, usually platinum. When this strip is subjected to heat its resistance increases, so that if it is connected in series with a sensitive galvanometer the deflection of the latter gives a measure of the temperature rise, and, consequently, of the intensity of the light which gave rise to the temperature increase.

The thermopile takes advantage of the fact that if two different metals are placed in contact, and the junction is heated, a small electric current is generated, the voltage depending upon the temperature of the junction. This device may be used indirectly to measure light intensity in the same manner as the bolometer, but neither form of instrument is sensitive enough to render it suitable for television purposes, and both are far too slow in their response.

Summing up, we find that selenium, while sensitive enough for television purposes, is far too slow in its response. The photoelectric cell, on the other hand, is practically instantaneous in its response, but it is lacking in sensitivity.

By using a photoelectric cell, however, many workers succeeded in transmitting shadowgraphs, or silhouettes of objects placed before the transmitter. In this case the question of the sensitivity of the cell is not of such importance, for it can be directly

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illuminated by a beam of light which may be as strong as we care to make it. As the object the shadowgraph of which is to be transmitted is interposed between the source of light and the photoelectric cell, all the latter has to do is to distinguish between a strong direct light and a dark shadow.

When transmitting shadowgraphs the illumination of the cell by the light source is *direct*; in television it is *indirect*. That is to say, when true television is to be accomplished, the source of light must be arranged to shine directly on to the object to be transmitted. Then the amount of light which reaches the photoelectric cell is that which is *reflected back* from the object on to the cell.

To those unacquainted with the subject there may not appear to be any particular significance in the above explanation, but the importance of it will be realised when it is explained that the total amount of light reflected from an object such as the human face, when it is illuminated by lamps of a thousand candle power, is less than that of a single candle. Furthermore, owing to the image-scanning process which occurs in television, whereby the image is subdivided into thousands of tiny pieces, or elements, only an infinitesimal fraction of this already very small amount of light reaches the cell at any given instant.

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# CHAPTER V

## THE TELEVISION EXPERIMENTS OF MM. BELIN AND HOLWECK IN FRANCE, AND MESSRS. JENKINS AND MOORE IN AMERICA

IN recent times the problem of television has been taken up seriously by Mr. J. L. Baird in this country, MM. Belin and Holweck in France, Mr. C. Francis Jenkins in America, and, more recently still, by the American Telephone & Telegraph Co. It is proposed to devote this chapter to an account of the work done by Messrs. Belin and Jenkins.

M. Belin (whose name is well known in connection with phototelegraphy), working in conjunction with M. Holweck, of the Radium Institute, Paris, has, it is stated, succeeded recently in sending shadows of simple objects. A diagrammatic outline of the apparatus used is given in Fig. 9, from which it will be seen that the arrangement of the transmitter is not unlike that of other systems.

Essentially the transmitter consists of two little vibrating mirrors, E and F, one placed above the other. The lower mirror, E, of very narrow width, oscillates vertically at



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a frequency of 500 cycles per second. The upper mirror, which is somewhat larger, oscillates horizontally at about 10 vibrations per second.

A beam of light from the arc lamp, A, passes through the system of lenses, B, the aperture in the diaphragm, C, the lens, D, and impinges upon the lower vibrating mirror, E. From this mirror the beam, oscillating vertically 500 times per second, is reflected on to the top mirror, F, which is vibrating horizontally 10 times per second. The resultant action is that from the upper mirror there is reflected a beam of light oscillating at two different frequencies, the planes of the two sets of oscillations being at right angles to one another.

If this beam were now projected upon a screen, the 500-cycle oscillation would cause it to traverse the screen continuously from right to left and back again from left to right; but as the beam is at the same time under the control of the 10-cycle oscillation, the 500-cycle lines, instead of being traced one on top of the other, will be drawn one below the other, as the 10-cycle oscillation steadily moves the beam in a downward direction. The entire screen would be illuminated in this way in one-tenth of a second, so that it would appear to an observer to be fully and continuously illuminated.

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[*Photo courtesy General Electric Co., U.S.A.*

AN EXPERIMENTAL FORM OF TELEVISION RECEIVER MADE BY THE GENERAL ELECTRIC CO. (U.S.A.).

The figure on the right is pointing to the motor which drives the disc. In his other hand he holds the manual control by means of which the receiver motor is kept running more or less in step with the transmitter mechanism. On the lower shelves are the batteries and amplifier. The neon tube is on the top shelf. See page 108.



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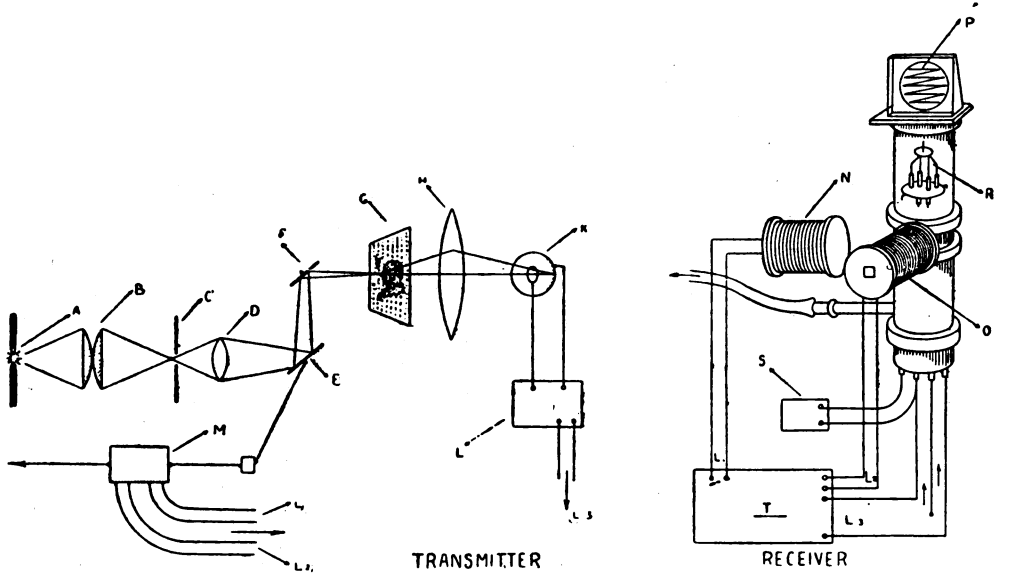


FIG. 9.—MM. BELIN AND HOLWECK'S TELEVISION APPARATUS.

A = Arc lamp. B = Condenser lens. C = Diaphragm. D = Lens. E = Vibrating mirror. F = Ditto. G = Transparency. H = Lens. K = Photoelectric cell. L = Amplifier. $L_3$ = Wires carrying light signals. M = Motor driving E and F. L, $L_2$ = Lines carrying A.C. currents. N, O = Magnets. P = Fluorescent screen. R = Terminal block of cathode-ray tube.

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A screen has been mentioned in the above explanation so that the reader may grasp how the light beam is caused to cover such a surface, and with what rapidity.

In the Belin apparatus the place of this screen is taken by an object the shadow outline of which it is desired to transmit, or by the lantern slide, G. Passing through the slide, the beam of light, made strong or weak in accordance with the transparent or opaque portions of the slide, is directed through the lens, H, which concentrates the fluctuating light beam on to the photoelectric cell, K.

The output of this cell is amplified and sent to the receiver, where it is caused to control the intensity of a cathode ray. The cathode-ray oscillograph which is used in this apparatus is the work of M. Holweck.

This oscillograph, the external details of which are shown in Fig. 9, is very similar in arrangement and operation to the cathode-ray tube already described in connection with Boris Rosing's experiments, although the details of the construction of the Holweck instrument are somewhat different. These details are shown in Fig. 10.

Above the filament, E, is placed a grid, G, which is a circular plate with a hole in the centre. Above this is a disc of similar form which acts like the anode or plate of a 3-electrode valve. This plate also has a hole

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in the centre, and over the hole is fitted a little copper tube. This arrangement concentrates the electron stream from the filament into a thin pencil-like discharge.

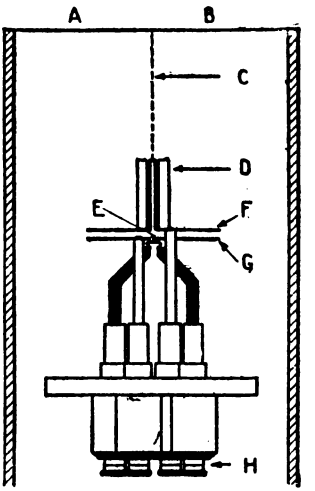


FIG. 10.—THE HOLWECK APPARATUS.

A, B = Fluorescent screen on which the electron stream, C, Traces a line of light. D = Concentrating coil. E = Filament. F = Plate. G = Grid. H = Terminals for the supply circuit.

The filament is brought to the correct electron emission temperature by means of a 2-volt battery. The varying input potential (i.e. the amplified output of the photoelectric cell of the transmitter) is applied between the grid and the filament. The plate voltage

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required is 1,500 volts, which is supplied by a special battery.

When this instrument is in operation, there is produced between the filament and the plate a stream of electrons which is "canalised" in the vertical tube, which is surrounded by the little concentrating coil, D. The action of this is to concentrate the stream of electrons into a very fine ray which is rendered visible when it strikes the fluorescent screen, AB, placed in the upper part of the oscillograph. The entire apparatus shown in Fig. 10 is kept in a high degree of vacuum by means of a Holweck molecular pump.

The action of the incoming current from the transmitter is to cause a disturbance in the normal emission of electrons, a disturbance which corresponds exactly with the variations of the modulated current at the transmitter. This disturbance is similar to that which takes place within a 3-electrode valve when a varying voltage is impressed upon the grid. A positive charge on the grid attracts some of the electrons, thus reducing the number of them which reach the plate. The grid of the cathode oscillograph acts in the same way, increasing or diminishing the total number of electrons which reach the fluorescent screen, in accordance with the current variations received from the transmitter.

The luminous point produced on the

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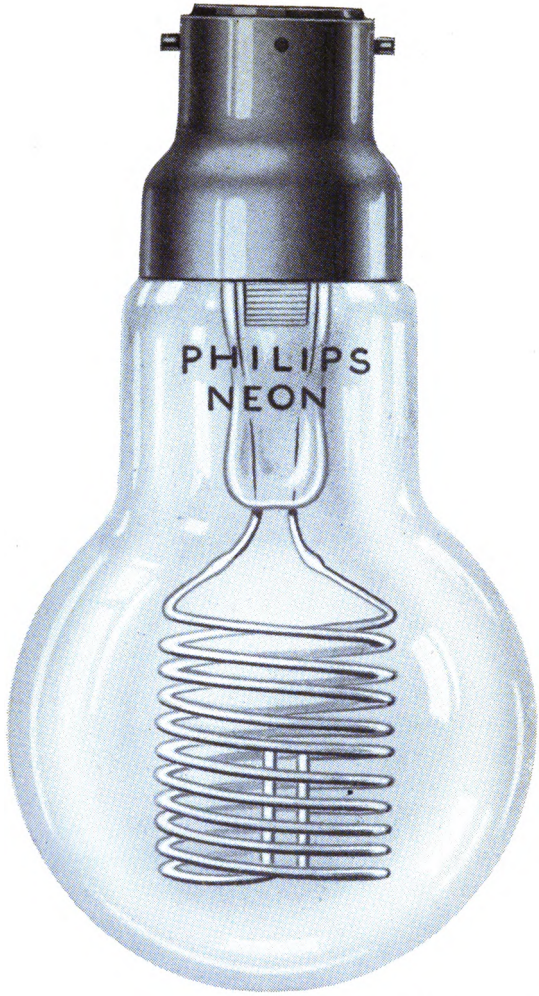


[*Photo courtesy Philips Lamps Ltd.*

A TYPICAL FORM OF NEON TUBE, SUITABLE FOR TELEVISION PURPOSES.



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[*Photo courtesy Philips Lamps Ltd.*

A TYPICAL FORM OF NEON TUBE, SUITABLE FOR TELEVISION PURPOSES.



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oscillograph screen varies in intensity in exact agreement with the beam of light falling upon the photoelectric cell at the sending station. If the point is kept fixed on the screen, its variations in intensity are very apparent.

We now arrive at the question of how the pencil of rays is caused to move to and fro across the fluorescent screen to reproduce the image.

As is well known, an electron stream can easily be diverted from its course by means of a magnetic field. This is demonstrated very clearly, in the oscillograph under consideration, by the small coil, D, which "canalises" the electron stream. When the coil is not excited the stream of electrons fills the copper tube, but when a current is switched on to the coil the stream is contracted and the trace which it produces on the screen shrinks up until it is only a tiny brilliant point. To achieve this tiny point is really the object of providing the coil, D.

If an ordinary bar magnet is brought near the oscillograph, the point of light on the screen will move away from it. If the magnet is removed, the point of light will return to the centre again.

Thus, in order to cause the cathode ray to bend to and fro across the screen, in sympathy with the action of the vibrating mirrors at



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the transmitter, it is only necessary to arrange two electromagnets at right angles to each other, so that the cathode ray is within the field of both of them. These magnets are shown in Fig. 9 at N and O. One of them is supplied from the same alternating current source which supplies the 500-cycle mirror, while the other is supplied from the same source as the 10-cycle mirror.

From what has been said above it will be seen that each of the magnetic fields will have the effect of displacing the cathode ray in exactly the same way as the visible light beam is displaced by the oscillating mirrors at the transmitter. As this displacement is effected by means of the same current which drives the mirrors, it follows that synchronism will be obtained between the transmitter and receiver; but, of course, it is necessary to send the two alternating currents (500 cycles and 10 cycles) to the receiver as well as the picture impulses. Three separate channels are therefore necessary.

In the Holweck oscillograph the cathode ray, instead of being allowed to strike the screen directly, is first bent round by means of a prism. This is done for convenience, so that the screen, instead of being in a horizontal position on top of the instrument, is fitted at an angle to the vertical which makes it easy to observe. The arrangement can be

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seen in Fig. 9, at P, the zig-zag lines indicating the track of the cathode ray as it moves to and fro across the screen to construct the image.

In the United States Mr. C. Francis Jenkins, who, like M. Belin, is well known in connection with phototelegraphy, has also succeeded in sending shadows, working in collaboration with Mr. MacTaggart Moore.

The Jenkins apparatus is of considerable interest by virtue of the fact that the optical system for scanning the image to be transmitted is of an entirely novel character. In the television systems so far described, light beams have been bent and moved about by means of mirrors. A prism, however, will also bend a beam of light. Aware of this fact, Jenkins cast about for some means of causing the beam also to oscillate, and his solution of the problem, known as the Jenkins Prismatic Disc, represents an entirely new contribution to optical science.

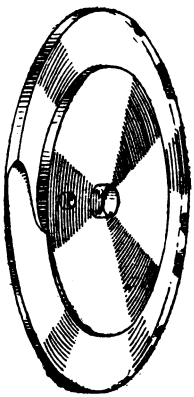

FIG. 11.—THE JENKINS PRISMATIC DISC.

One of these prismatic discs is illustrated in Fig. 11. It consists essentially of a disc of thick glass, the outer edge of which has been ground into the shape of a prism, the

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section varying gradually and continuously round the circumference, so that at one point the base of the prism is outward, while diametrically opposite this point the base is inward.

If a beam of light be directed through the edge of such a disc it will be bent in a certain direction, the angle at which the beam bends depending upon the angle of the prismatic section at that point. For the sake of example let us say that the beam is directed upwards at an angle of 45 degrees. If, now, the disc be slowly revolved, the beam will begin to move. If we are turning the disc in the right direction, the beam will move slowly downwards in a vertical plane, until, when a complete revolution of the disc has been made, the beam will be found to be pointing downwards at an angle of 45 degrees.

By superimposing a second disc over the first (as shown in Fig. 12), so that their overlapping edges revolve in directions at right angles to each other, a lateral movement can be given to the beam, as well as a vertical movement. Thus Jenkins got the two necessary oscillatory actions. It is necessary, of course, for one of the discs to revolve comparatively slowly, to space the image lines traced over the photoelectric cell, or on the screen; while the other disc must revolve much more rapidly in order to trace the image lines.

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In some forms of the Jenkins apparatus, four revolving discs are used, but this duplication is introduced merely for the purpose of giving optical correction; it does not alter the principle of operation. In electrical

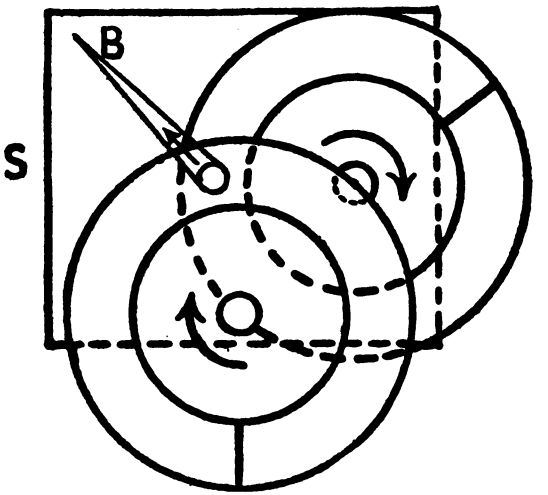


FIG. 12.—THE ARRANGEMENT OF THE JENKINS PRISMATIC DISCS.

The combined action of these revolving discs is such that the light beam, B, is caused to cover the screen, S, with parallel lines, set closely together.

parlance, the two pairs of discs might be described as working in parallel.

In order to project on to the photoelectric cell an image of the object or scene to be transmitted, Jenkins uses a magic-lantern projector, into which is inserted a lantern

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slide of the scene to be transmitted. The beam of light issuing from the lens of the lantern passes through the prismatic sections of the revolving discs. The action of these discs, as explained above, is to sweep the beam (containing within it the image) across the photoelectric cell.

At the receiver, the incoming impulses from the photoelectric cell are caused to control the degree of brilliancy of a special form of neon tube developed by Mr. Moore. A beam of light from this tube is then focused through a system of revolving prismatic discs similar to that in use at the transmitter. The action of these discs, at the receiver, is to spread the neon tube light beam over the receiving screen and thus reproduce the image.

Neon tubes consist essentially of two electrodes sealed into a glass vessel in which the air has been replaced by neon gas at a very low pressure. When a current of electricity is forced through such a tube by means of a high voltage, the tube glows brilliantly, due to the heating of the atoms of gas by the passage of the current. Such tubes are being used a great deal, nowadays, for illuminated advertising display purposes. They can easily be recognised by their brilliant red glow.

We have already seen, in connection with our consideration of light-sensitive devices, that in television we have to deal with im-

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pulses occurring at frequencies running into many thousands per second. Not only is it necessary for the light-sensitive device to respond to impulses at such enormous frequencies; the source of light at the receiver must respond with equal alacrity.

Laboratory tests have shown that lamps of the neon glow discharge type can be lighted or extinguished at the rate of more than one million times per second. Another point of importance in television work is that such lamps produce a degree of illumination which is directly proportional to the amount of current supplied to them.

Two views of the type of neon tube, specially developed by Mr. Moore for television purposes, are shown in Fig. 13. The outer electrode, shown at B in the sectional sketch, is the negative electrode, while the inner electrode, A, is positive. When a difference of potential is established between these two electrodes the gas within the tube glows. Immediately the current is switched off the light instantly ceases.

The special construction adopted is such that the illumination is all from the point in the middle of the centre electrode. This not only concentrates the light, making it appear to be more intense, but it also facilitates the use of lenses for focusing purposes.

In his earlier experiments in connection

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with phototelegraphy, Mr. Jenkins secured synchronism between his transmitting and receiving mechanisms by means of an electrically driven tuning-fork arrangement. As will be explained later on, such an arrangement is not sufficiently accurate for television

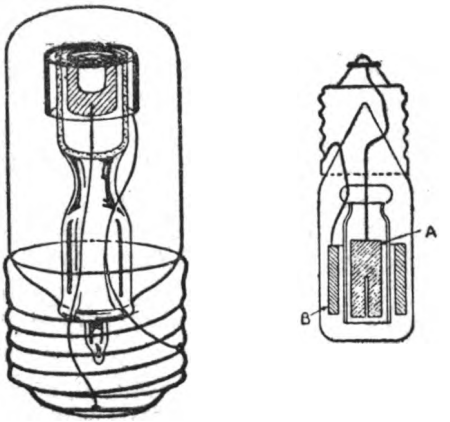


FIG. 13.—TWO VIEWS OF THE MOORE NEON TUBE.

purposes, and for his television experiments Mr. Jenkins now makes use of synchronous electric motors to drive both transmitter and receiver mechanisms.

Details of such motors will be given in a later chapter. For the present it is sufficient to say that two or more such motors, running off the same alternating current supply, *must*

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[*Photo courtesy American Telephone & Telegraph Co.*

MR. W. S. GIFFORD, PRESIDENT OF THE AMERICAN TELEPHONE & TELEGRAPH CO., SPEAKING FROM NEW YORK TO SECRETARY HOOVER IN WASHINGTON, AND AT THE SAME TIME WATCHING MR. HOOVER'S FACE ON THE SMALL TELEVISION SCREEN BEFORE HIM.

On the right is Dr. Ives, who was in charge of the experiments. See Chapter VIII.



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keep in step, i.e. run at exactly the same speed. Since large American manufacturers of alternating current generators claim that in all their large installations they can guarantee that the difference in frequency between any two plants is less than ½ per cent., this, according to Jenkins, guarantees the accuracy of operation of his television machines in many localities where the standard American supply of 110 volt, 60-cycle A.C. is available; for the only factor which will cause a synchronous motor to vary in speed is a variation in the frequency of the supply.

At this low frequency, however, the phenomenon known as phase swinging may prove fatal to reproduction; for although the mean speed is constant, an A.C. motor, if of low frequency, may vary its instantaneous speed quite considerably, and any such variation would seriously impair reception.

In the latest type of Jenkins machine, particulars of which are available, the lens disc carries forty-eight lenses, and the purpose of the apparatus is avowedly to transmit and receive, not television, but special cinematograph films. Using a wave-length of 300 metres, Mr. Jenkins has recently been broadcasting these special shadow films from his laboratory in Washington. There is no detail in the films, only a plain black-and-white

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silhouette of simple scenes such as a little girl bouncing a ball.

The films are reeled off through the transmitter at the rate of fifteen pictures per second—one less than the ordinary cinematograph. They are reproduced at the receiver at the same rate, and the received images, viewed through a magnifying glass, appear to be about six inches square. According to witnesses' reports, the received shadowgraphs are very clear, and the illusion of motion is excellent.

The general layout of the new Jenkins animated shadowgraph transmitter is shown in Fig. 14. The film reels are mounted on a simple framework, one above the other, in such a manner that the film is pulled downwards by a set of sprockets which are driven by an electric motor. One end of the shaft which drives the sprockets is fitted with a gear pinion which meshes with another smaller one.

The small pinion is mounted directly on the shaft of the electric motor, which is a synchronous A.C. motor capable of running at 1,800 r.p.m. Because of the speed-reducing action of the gears, the pictures are pulled past the sprockets, or any fixed point next to the film, at the rate of 900 per minute, or 15 per second.

At the other end of the shaft which drives

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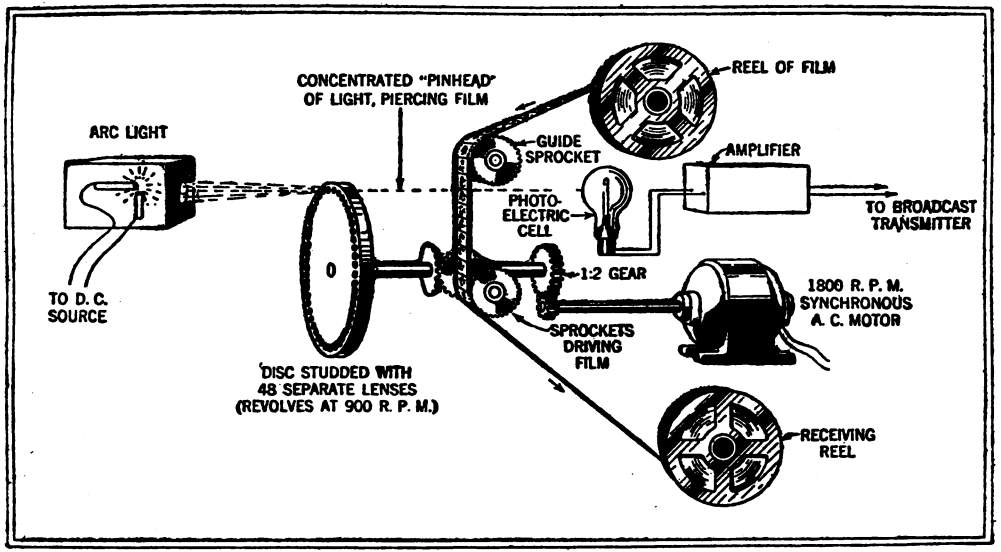


FIG. 14.—ILLUSTRATING THE GENERAL ARRANGEMENTS OF C. FRANCIS JENKINS' NEW MOVING SHADOW-GRAPH TRANSMITTER.

The leads marked "to broadcast transmitter" go to the regular input amplifier of the wireless transmitting station through which the images are being sent.

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the sprockets is a heavy metal disc, about fifteen inches in diameter and about one inch thick. The edge of this disc is studded with forty-eight separate little lenses, each of which has an "optical speed" of *f.* 3·5. These lenses are designed to concentrate the light from a powerful arc lamp into an intensely brilliant "pinhead" beam, which is caused to pierce the film as the latter travels down past the back of the disc.

Immediately behind the film is mounted a photoelectric cell, which is so placed that the "pinhead" beam of light, after passing through the film, impinges upon it. The cell is connected to a three-stage resistance-coupled amplifier, the output of which is connected to a further amplifier of similar design, but having eight stages. Both amplifiers are very heavily screened by double copper shields.

A close study of Fig. 14 will make the operation of the apparatus clear. The lens disc revolves at 900 r.p.m., or fifteen times per second. The separation between the centres of the lenses is just equal to the width of the film. The latter moves steadily downwards at the rate of fifteen pictures per second. Its action is not jerky, as in a cinematograph projector.

The arc lamp on the left projects a powerful converging beam of light through one of the

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lenses of the disc, which lens further converges the beam to a point, which " scans " or travels across the film from one side to the other, due to the rotary motion of the disc. When the next lens picks up the beam from the arc lamp, the film has moved downwards slightly, so that the second beam travels across the film on a parallel but slightly higher path.

Succeeding lenses of the disc trace further parallel paths across the film, until each picture has been explored by the forty-eight lenses. As soon as the beam of light from one lens runs off the film, the beam from the succeeding lens starts to pierce the film on the other side. This movement is continuous during the operation of the mechanism.

Thus forty-eight separate beams of light travel across each individual picture in one-fifteenth of a second. At the start of each fifteenth of a second period a fresh picture slides into position and another series of forty-eight light beams starts to pierce it.

While this movement is taking place the light beams, after shining through the film, fall on the photoelectric cell with degrees of intensity which depend upon the density of the parts of the film through which they shine. The electrical output of the photoelectric cell varies in proportion to the variation of the light intensity, and, after

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amplification, this varying current is caused to modulate the radio broadcast transmitter.

The apparatus for receiving these transmissions has many points of difference from any other receivers described in this book. It is illustrated in Fig. 15, and consists of six essential parts. The heaviest unit is a 3,600 r.p.m. synchronous A.C. motor, to the shaft of which is attached a hollow metal drum about seven inches in diameter and about five inches wide. The centre of this drum is a hollow spindle with a thin wall.

In corresponding places on the drum and the spindle are four spiral rows of tiny holes, twelve holes to a row. A short piece of quartz rod between the outside and inside connects each pair of corresponding holes. The purpose of the forty-eight little quartz rods is to conduct light from the inner spindle to the holes in the outer drum with as little loss as possible.

Fixed inside the hollow spindle, with the flat little plates facing directly outward, is a special neon tube having four discharge electrodes. This tube is about four inches long and one inch in diameter, the little discharge electrodes, or plates, being about one-quarter of an inch square. A straight wire running near the four electrodes acts as a common element. In Fig. 15, this tube is shown

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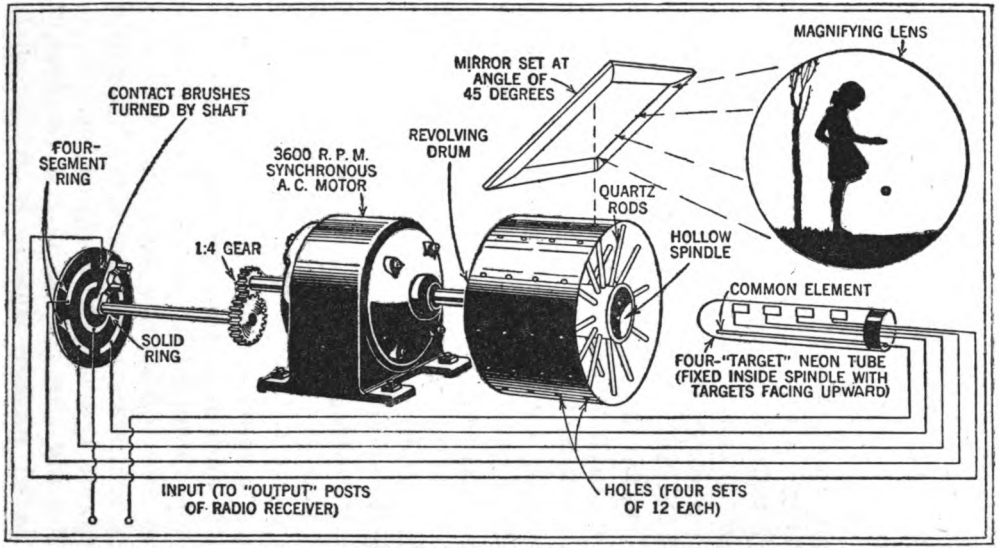
MAGNIFYING LENS
MIRROR SET AT ANGLE OF 45 DEGREES
CONTACT BRUSHES TURNED BY SHAFT
REVOLVING DRUM
FOUR-SEGMENT RING
3600 R. P. M. SYNCHRONOUS A. C. MOTOR
QUARTZ RODS
HOLLOW SPINDLE
1:4 GEAR
COMMON ELEMENT
SOLID RING
FOUR-"TARGET" NEON TUBE (FIXED INSIDE SPINDLE WITH TARGETS FACING UPWARD)
INPUT (TO "OUTPUT" POSTS OF RADIO RECEIVER)
HOLES (FOUR SETS OF 12 EACH)

FIG. 15.—THE GENERAL ARRANGEMENT OF THE NEW JENKINS RECEIVER.
The whole apparatus is enclosed in a wooden box, on top of which is mounted the mirror and viewing lens.

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withdrawn from the spindle, in order to illustrate it; in actual use it fits inside the latter without touching it.

The other end of the motor shaft is fitted with a 1:4 reducing gear which drives a revolving switch. The revolving element is simply a pair of contact brushes connected together. One brush effects continuous electrical connection with a solid brass ring imbedded in an insulating disc, while the other makes a wiping contact over the four sections of a split ring. The four segments are connected to the four discharge electrodes of the neon tube, while the solid ring is connected to one of the output terminals of the radio receiver. The common element of the neon tube is connected to the other output terminal of the wireless receiver.

All the receiving apparatus described so far is contained in a wooden box measuring about two feet long and a foot square at the end. Directly above the top of the revolving drum is a square opening in the top of the cabinet, and over this opening an ordinary mirror is mounted at an angle of 45 degrees to the top. About a foot in front of the mirror, and standing upright, is a magnifying lens about ten inches in diameter.

Following the action of the receiver, the modulated picture signals from the distant transmitter are picked up by an ordinary

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THE DAYLIGHT TELEVISION TRANSMITTER ON THE ROOF OF THE BAIRD LABORATORIES.
The man whose image is being transmitted is sitting in the chair, facing the lens disc, which is revolving behind the opening in the side of the shed. See Chapter XIV.



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wireless receiver, amplified, and fed to the moving-picture receiver. Assuming that the contact brushes have just made contact with the upper right-hand ring, as shown in Fig. 15, and that one of the quartz rods in the first, or outermost circle, is pointing straight up, this condition corresponds with the start of a picture in the transmitter, when the light spot is just commencing to sweep across the film.

As the contact brushes have just closed the circuit to the neon-tube electrode at the extreme right, this electrode lights up immediately and fluctuates in brilliancy exactly in accordance with the modulation of the signal. The fluctuations of light are carried up the quartz rods and projected through the holes in the outer drum upon the mirror. The light thus reflected from the mirror follows the shading of the images on the original film, so that a picture is built up in the mirror. This picture may then be observed through the magnifying glass.

A complete picture of forty-eight lines (corresponding to the rate of transmission) is built up on the mirror with every four revolutions of the drum. At the beginning of the second revolution, the contact brushes turn to the next segment of the switching ring (because of the gearing) and the second electrode of the neon tube becomes operative.



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The third and fourth quarters of the picture are similarly built up from the third and fourth electrodes, and the cycle then commences again with the first electrode. During one second the drum revolves sixty times. Since four revolutions create one picture, sixty revolutions create fifteen pictures, which gives the speed of fifteen pictures per second mentioned when the action of the transmitter was being described.

It is, of course, necessary for the transmitting and receiving mechanisms to run absolutely in synchronism, but Jenkins does not provide any special synchronising method. For the purpose of the demonstrations given in Washington the transmitter and receivers were driven by synchronous A.C. motors, and as all the motors took their power from the same power line, it is reported that little difficulty was experienced in keeping the pictures steady.

Witnesses describe the pictures, as viewed at a distance of about ten feet from the magnifying lens, as being clean-cut silhouettes against the characteristic reddish background provided by a neon tube.

This apparatus is interesting, and distinctly novel, but it should be clearly understood that it does not produce television. It transmits and reproduces only moving shadowgraphs of simple figures and scenes

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which have previously been specially prepared and recorded on a standard cinematograph film; and as there are no refinements of shading and detail to be handled, the problem of designing suitable apparatus is vastly simpler of solution than is the problem of designing apparatus which will enable true television to be accomplished.

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# CHAPTER VI

## THE PIONEER WORK OF J. L. BAIRD. EARLY APPARATUS

WE have, in the preceding chapters, dealt exclusively with work done abroad by television investigators. Of the many workers who have interested themselves in the subject, we have, for reasons already given, described the apparatus of only a few, but the work of these few may be taken as being fairly representative of the methods and equipment adopted by many others.

We must now turn to a consideration of the work done in our own country by Mr. J. L. Baird, to whom belongs the credit and distinction of having been the first man actually to demonstrate publicly true television. Nearly fifty years ago, the inventive genius of Graham Bell, a Scotsman, gave to the world the telephone, and now Mr. Baird, another Scotsman, in successfully demonstrating television, has given us an electric eye to add to the electric ear supplied by Bell.

It is now about five years ago since Baird,



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compelled by ill-health to abandon an active business career, commenced to devote himself exclusively to a study of the problem of television. Prior to that time, however, scientific research had always been his hobby, and in the early days of his training as an engineer he devised an improved form of selenium cell, which led him to develop a crude system of television.

When, as a result of the breakdown in his health, he was compelled to lead the life of a recluse, Baird took up the threads of the television problem where he had left off years previously.

At first glance the problem seemed simple of solution. Briefly reviewed, the requirements, as we have already seen, may be stated as follows:

(1) Means of scanning an image, so as to subdivide it into tiny sections, or elements.

(2) Means of transforming the resulting picture elements, or light impulses, into electrical impulses, which can be transmitted to the distant receiver, either by wire or wireless.

(3) Means of reconverting electrical impulses into light impulses, and by means similar to (1), causing them to cover, or illumine a screen, thus reproducing the image at the transmitter.

(4) Means of synchronising the transmitter

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and receiver, i.e. causing them to run in step, or exactly at the same speed.

These are the requirements as Baird reviewed the subject five years ago, and, on paper, the problem seemed simple. Many optical methods were already known which would fulfil requirement (1). The selenium cell and the photoelectric cell were in existence and seemed to cover requirement (2); and for (3) there was the neon tube. Methods of synchronism had already been developed to a high degree in connection with other electrical processes, notably as an aid to high-speed multiplex telegraphy, so that point (4) seemed to be covered.

It all seemed very simple, so simple, in fact, that the wonder was that television had not already been accomplished. Baird concluded that there must be a catch somewhere. There was; and as we have already seen, the stumbling block lay in requirement (2), the light-sensitive cell. Another catch lay in the fourth requirement, for the usual methods of synchronism, although satisfactory for the purposes for which they were developed, were quite unsuitable for television.

After about six months' work, however, Baird achieved a measure of success, and was able to transmit shadowgraphs. Encouraged by this success, hope ran high, but, as other

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inventors have found, he soon discovered that to transmit shadows was one thing; to transmit the images of the objects themselves was a very different thing.

Month after month he worked with apparatus of the very crudest description, until, in April 1925, he had the satisfaction of giving the first public demonstration of television, transmitting outlines by wireless between two separate machines at Selfridge's Oxford Street store. As stated, only outlines were transmitted on this occasion, but they were transmitted by light reflected from the original objects, and were not shadows.

In connection with his efforts to progress from the transmission of outlines to the sending of true images complete with detail, Mr. Baird is fond of telling the following story:

For the purposes of his experiments he was in the habit of placing before the transmitter the head of a ventriloquist's doll, and his efforts were concentrated in the direction of getting not merely the outline, but a complete detailed image of this doll through to his receiving screen. One day, in October 1925, after months of patient effort, he had the satisfaction of seeing the doll's face on his receiving screen not as an outline, but as a real image with shading and detail.

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Full of enthusiasm and excitement, Mr. Baird rushed out of the laboratory in search of a human "subject" to take the place of the doll. The first human being he met happened to be Mr. William Taynton, who was at that time office boy in the office below. After some difficulty Mr. Baird persuaded Mr. Taynton to come up to the laboratory and take his place before the Televisor.

After seating him in the correct position, Mr. Baird dashed through the laboratory to look at the receiving screen. To his great disappointment however, there was nothing to be seen. After vainly trying various adjustments he went back to the transmitter, to find that the failure of the experiment was due to the fact that his human subject, afraid of the terrific glare of the lights used to illuminate his face, had moved back out of focus.

"In the excitement of the moment," to quote Mr. Baird, he was given half a crown to take up his position again and maintain it. This time the image of the boy's face came through clearly on the receiving screen.

As a matter of historical interest it is somewhat strange to have to record that the first human being ever to be televised had to be bribed to accept the distinction!

After several more months of hard work, Baird was able, on January 27th, 1926, to give to over forty members of the Royal

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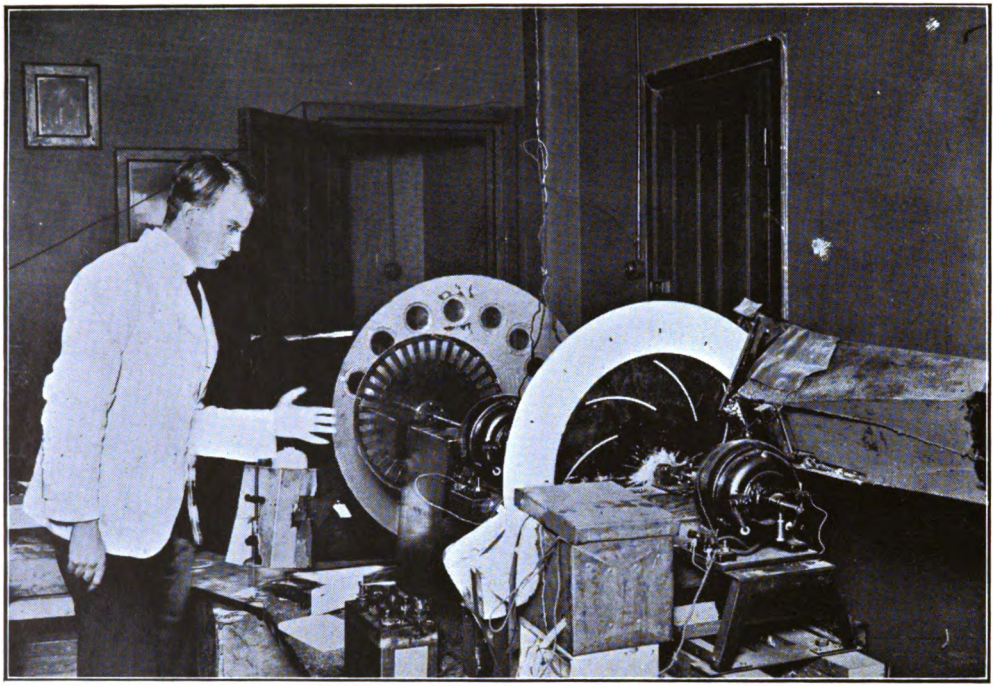

J. L. BAIRD WITH ONE OF HIS EARLIEST EXPERIMENTAL MACHINES.



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Institution the first demonstration of true television ever witnessed. The image of moving human faces were transmitted between two rooms, not as outlines or silhouettes, but complete with tone gradations of light and shade and detail. Although the received images flickered a great deal, and suffered from other defects, the individual being "televised" could be recognised.

This demonstration, and others which followed shortly after, created considerable interest, but Baird's weird apparatus, consisting of old bicycle sprockets, cardboard discs, and bullseye lenses, all tied together with sealing wax and string, failed to impress those who were accustomed to the shining brass and exquisite mechanism of the professional instrument maker. The importance of the demonstration was, however, realised by the scientific world, and many leading scientists and engineers came to inspect the apparatus.

The original transmitting mechanism shown at Selfridge's is now on exhibition in the South Kensington Science Museum, and its mode of operation will be described with the aid of the diagrammatic sketch given in Fig. 16, where A represents the object the image of which is to be transmitted, and the revolving discs B, C, and D are the image-scanning, or exploring mechanism.

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The disc B, carrying a series of lenses in staggered formation, rotates at about 800

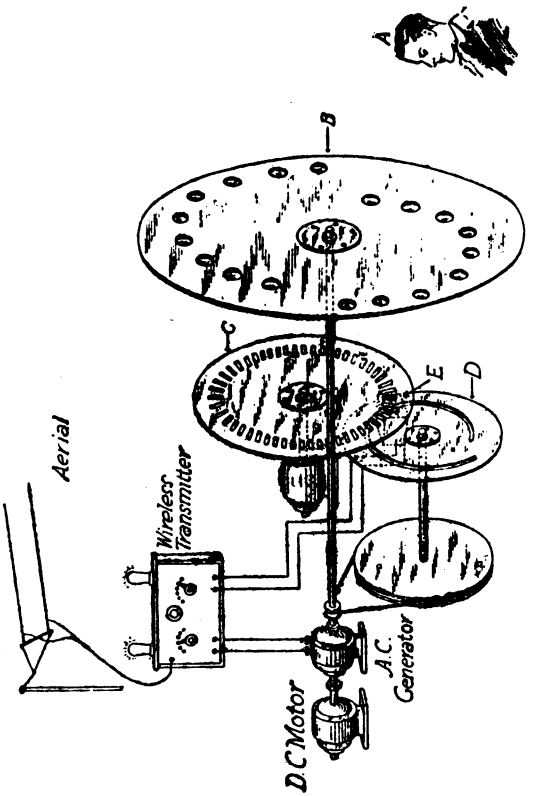


FIG. 16.—SKETCH OF BAIRD'S ORIGINAL TRANSMITTER.
A = The object to be transmitted. B = A revolving disc with lenses. C = A slotted disc revolving at high speed. D = A rotating spiral slot. E = The aperture through which the light passes to the light-sensitive cell.

r.p.m., and causes a series of images of A to pass, in the form of long strips, across the light-sensitive cell, E. Before reaching E,

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however, the image strips are broken up by the slots in the disc C, which revolves at about 4,000 r.p.m. Passing through the serrations of this disc, the light impulses must also shine through the spirally slotted disc D, the rotation of which has an effect which is equivalent to giving the light-sensitive cell, E, a back and forward motion, thus dividing the image into a greater number of strips. That is to say, the action of D is equivalent to using more lenses in B. The disc D revolves at a comparatively slow speed.

The picture-analysing action of the revolving discs may be summarised as follows. The lens disc, B, divides the image up into, in this case, sixteen strips. This number of strips is doubled by the disc D. Disc C chops up individual image strips into a series of light flashes. Thus the entire picture is analysed into thousands of light flashes, or picture elements, which are arranged to fall upon the light-sensitive cell, E, in regular succession.

The output of the light-sensitive cell, of course, varies in direct proportion to the intensity of the light flashes falling upon it, and this output, after amplification, is transmitted to the receiver, either by wire or by wireless. Superimposed upon this picture impulse current there is also an audio frequency current from the A.C. generator, shown

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coupled to the motor which drives the revolving discs. This audio frequency current is transmitted to enable the receiver to be synchronised with the transmitter. This part of the apparatus will be more fully explained in the chapter devoted to methods of synchronism.

At the receiver, shown diagrammatically in Fig. 17, the synchronising current, superimposed upon the picture impulse current, is filtered out, and caused to operate (after amplification) the synchronous motor which governs the speed of the main D.C. motor.

At present, however, we are concerned only with the picture impulses.

At the receiver, these impulses are caused to operate a neon tube, K, which type of tube, as we have already seen, responds instantly to current impulses, transforming them into light flashes.

The optical mechanism, or image-scanning device, closely resembles that at the transmitter, with the exception that, in the case of the receiver, the serrated disc, C, is eliminated, leaving the slotted disc, H (Fig. 17), and the lens disc, G (Fig. 17). The combined action of these two discs is to bend a beam of light from the neon tube, K, to and fro and up and down, so that the screen, F, is fully illuminated, the fluctuations in the illumination of the neon tube, K, being spread

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over the screen so as to reproduce exactly the original scene at the transmitter.

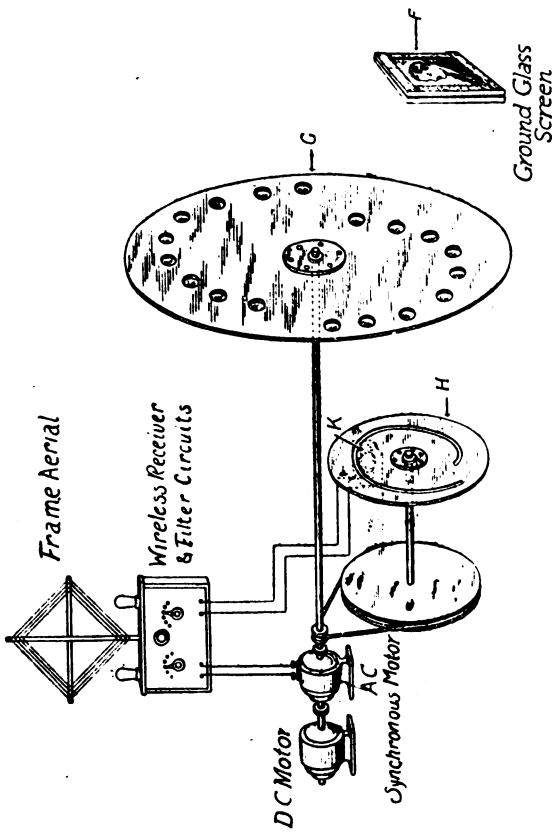


FIG. 17.—BAIRD'S ORIGINAL FORM OF RECEIVER.
F = Reproduced image. G = Revolving disc with lenses. H = Rotating spiral slot.
K = The aperture through which the light passes from the varying light source.

Although, as already stated, the above-described apparatus functioned satisfactorily,

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and gave true television, the "grain" of the received image was very coarse. Compared with the modern cinematograph, it was as a newspaper reproduction is to a fine art reproduction in a high-grade illustrated magazine. The details and the gradations of light and shade were there, and the picture could be recognised, but the reproduction left much to be desired.

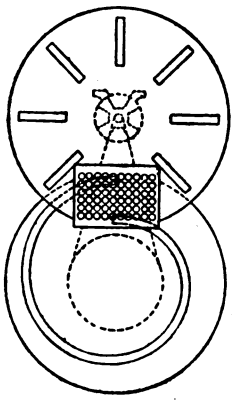

FIG. 18.

As the two discs revolve behind the cellular structure, the combination of the spiral slot of one disc with the radial slots of the other disc exposes the light-sensitive cell to the light impulses of individual tubes, one by one.

In an effort to improve the grain of his image, Baird experimented in several directions. Three methods of casting an image are known to optical science. We have the lens, the concave mirror, and the pinhole.

Another interesting device has, however, been described in one of Mr. Baird's patents. This is a somewhat unusual honeycomb structure made up of a bank of small tubes arranged in parallel rows. The action of this bank of tubes is rather peculiar.

If held, for example, in front of an electric-light bulb an image of the filament will appear on a ground-glass screen held close against

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the back of the bank of tubes. A surprising feature of the image is that it is constant in size, independently of the distance between the bank of tubes and the lamp.

This is a property which differs entirely from other image-casting devices wherein the size of the image is dependent upon the distance away of the object from the image-casting device.

Whether this particular apparatus will find a permanent use in television remains to be seen, but we describe it as an interesting scientific novelty which has been tried experimentally as a substitute for a revolving lens disc. The two interrupter discs, C and D (Fig. 16), were retained, and arranged to operate in conjunction with the cellular structure as shown diagrammatically in Fig. 18.

As already stated, Baird's original machine gave an image at the receiver which appeared to be made up of thin closely fitting strips. By using the system of projection tubes mentioned above, the received image takes on the appearance of being made up of a large number of fine dots.

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## CHAPTER VII

### THE PIONEER WORK OF J. L. BAIRD (*continued*). THE "OPTICAL LEVER." MULTIPLE CHANNELS

OF the many image-exploring devices devised to date, both by Baird and by other workers, none is so highly interesting and fraught with possibilities as Baird's latest invention, called by him an "optical lever." The possibility of speeding up all other devices is strictly limited by mechanical considerations, but with the optical lever there is no limit to the speed at which light impulses may be caused to traverse the light-sensitive cell, or a bank of several cells.

This invention is described in Baird's Patent No. 265,640, and to describe it we cannot do better than quote from the original specification and refer to the original sketch, which is reproduced in Fig. 19.

Quoting from the patent specification: "The transmitter may consist of a rotating disc, around which is arranged a circle of lenses. In front of the disc is the object to be transmitted, and behind the disc and in the



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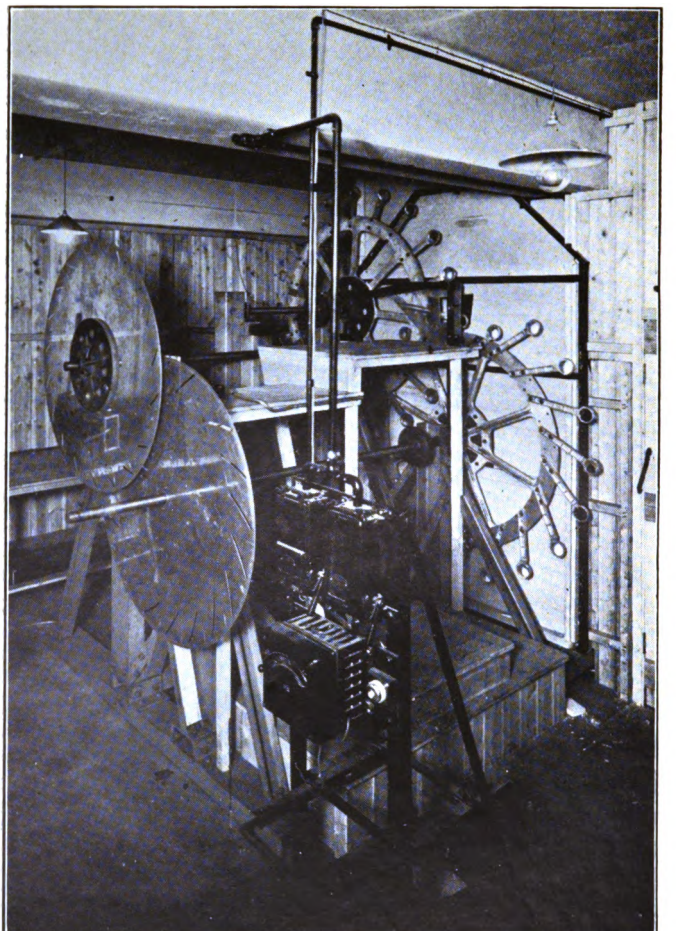

A CORNER OF THE BAIRD LABORATORIES, SHOWING THE MECHANISM OF ONE OF THE MORE RECENT TELEVISION TRANSMITTERS.



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focal plane of the lenses is a ground-glass screen. As the disc rotates a series of images of the object pass from top to bottom across the screen.

"Behind the screen is a second revolving disc containing a circle of lenses. This disc throws an image of the ground-glass screen on to a diaphragm containing an aperture leading to a light-sensitive cell, and is arranged so that, as it revolves, the images cast by its circle of lenses move from one side to the other across the diaphragm (see Fig. 20). The image of the object when it reaches the diaphragm has therefore two motions; from top to bottom, due to the first disc, and laterally, say from left to right, due to the second disc, the second disc revolving slowly relatively to the first, and thus the image traverses the cell."

A ground-glass screen has been mentioned to make the action of the mechanism somewhat clearer, but it is not necessary and, in practice, is omitted. The lenses in the disc may be arranged in spiral or any staggered formation, and to give the lateral motion to the image a revolving mirror polyhedron may be used in place of the second disc.

The above is a general statement of the principle of the methods used.

To obtain a finer grain in the image it is necessary for it to pass very rapidly over the



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cell, and in order to increase the speed without increasing the speed of the revolving discs, or adding lenses, more than one combination of discs is used. Another method of increasing the speed consists of employing a bank of fixed lenses, say three, each lens casting an image of the object on to a ground-glass screen. As the lenses are adjacent the three images will be almost identical. An image of this screen is then made to traverse the light-sensitive cell by any of the means previously described, only, by the use of three fixed image-casting lenses, the speed is trebled. As before, the ground-glass screen may be dispensed with.

"The lenses may be arranged to work with more than one cell. For example, a set of nine lenses might be used casting three images on the screen, each of these three rows operating its own cell, which would control its own light source at the receiving station, the light source replacing the cell behind an optical device similar to that at the transmitting station."

Referring now to the diagrams, Fig. 19 is a plan of the apparatus; Fig. 20 is a partial end view looking in the direction of the arrow A; and Fig. 21 is an end view looking in the direction of the arrow B. In the following description, ground-glass screens will be mentioned, as they enable the action of the system

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to be followed more easily. Actually they are not essential to the performance of the apparatus, and are omitted in practice.

Referring to Fig. 19, the image-scanning mechanism, or transmitter, consists of a rotatable disc, 1, in which is mounted any desired number of lenses, 2. In front of the disc is the object, 3, or objects, of which a reproduction is to be transmitted. The position of the first ground-glass screen is shown at 4, it being so mounted as to receive an image projected by one of the lenses, 2. The line 18 indicates the optical axis of the apparatus, along which projection of the images takes place; and when one of the lenses, 2, crosses this axis an image is projected upon the screen, 4.

Behind the screen, 4, is a second rotatable disc, 5, also carrying a suitable number of lenses, 6, and so positioned that these lenses, by rotation of the disc, are carried across the optical axis, 18. The discs 1 and 5 are mounted on separate parallel shafts, 7 and 8, which are rotated at any desired speeds. They may, if desired, be geared together.

The image projected on to the screen, 4, constitutes an object of which an image is projected by each of the lenses, 6, on to a screen, 9, placed behind the disc, 5; and the rotation of the shafts, 7 and 8, is made so that the lenses, 2, cross the optical axis, 18, in the

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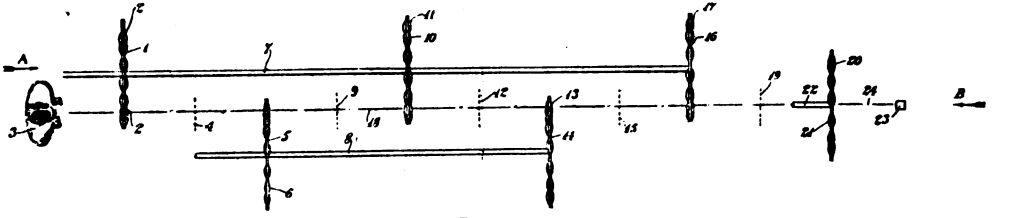


FIG. 19.



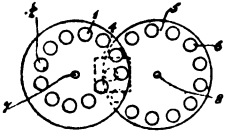


FIG. 20.

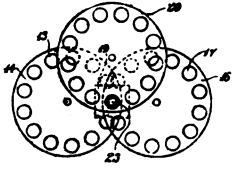


FIG. 21.

BAIRD'S OPTICAL LEVER.

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opposite direction to the lenses, 6. With the construction shown, this result is obtained by rotating the discs in the same direction.

"The shaft 7 carries a further series of discs having mounted on it a plurality of lenses as indicated at 10, 11 and 16, 17, these lenses all being arranged to be carried across the optical axis, 18, by the rotation of the shaft 7. Similarly, the shaft 8 carries a series of discs each with a plurality of lenses on it as indicated at 13, 14, and these discs are intercalated with the discs on the shaft 7. The lenses on each of the discs as they cross the optical axis 18, reproject successively from the left towards the right in Fig. 19, the image cast by the lens on the preceding disc in the series, and as the lenses are moving successively in opposite directions the speed of traversal of each successive image is increased. Any desired number of discs may be used on each shaft so as to provide any desired final speed of traversal of the image."

The most difficult point to understand in connection with this invention is just how it comes about that the speed of traversal is increased. At first glance it would appear that no advantage would result from increasing the number of discs, and that the images cast by successive discs would, in any case, just pile one on top of the other on the last screen of the series. Such, however, is not the case.

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All motion is relative. In order to decide what is motion and what is not, and the speed at which an object moves, we must have some fixed point of reference. A person may walk along the corridor of a train at a speed of three miles an hour. Persons sitting in the compartmnets would say he was moving at the rate of three miles an hour, which would be correct from their point of view, i.e. using themselves as the point of reference.

But if the train itself were travelling at sixty miles an hour, and the person concerned happened to be walking from the back of the train towards the front, his total rate of progress, using the surface of the earth as the point of reference, would be sixty-three miles an hour.

When we consider that the earth itself is moving through space, revolving round the sun, and round its own axis, then we see that the rate of progress of the person walking along the train, and the speed of the train itself, is, if we take the sun as the point of reference, something altogether different to what we imagined it to be.

Returning now to the optical lever, the lenses, 2, of the first revolving disc cast on the screen, 4, a series of images of the relatively fixed object, 3. The lenses, 6, of the second disc, which cross the optical axis in the opposite direction, pick up an image of screen

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4 and cast it on to screen 9. From the point of view of the second disc, the image on screen 4 is the relatively fixed object, a series of images of which it has to project on to screen 9. But by virtue of the fact that the image on screen 4 is not a fixed object, but a series of rapidly recurring images; and by virtue also of the fact that the lenses on the first and second discs are moving in opposite directions, the total number of images which will fall on screen 9 in a given time will be twice the number falling on screen 4. The second disc really handles images at the same speed as does the first disc, but whereas the first disc is projecting images of a fixed object, the second disc is, as it were, projecting images of a number of rapidly moving objects.

The third disc, 10, now picks up the image of screen 9 (which, from the point of view of the third disc, is also a relatively fixed object) and reprojects it on to screen 12, thus effecting still another increase in the speed of traversal; and further increases are effected by the succeeding discs in the series.

Thus the speed of traversal of the images is increased by what may be described as an optical lever effect; hence the name which has been given to the device. At each successive screen the speed of traversal of the images is twice what it was on the preceding one; and the increase may be carried to any extent by

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adding more discs to the series, whilst maintaining the speed of the mechanism itself within permissible limits.

As already mentioned, screens are not actually necessary; they have been quoted in the description given above, and shown in Fig. 19, simply as an aid to the understanding of the apparatus. As they cross the optical axis the lenses on each disc will pick up the images cast in space by the lenses of the preceding disc.

With the arrangement shown, the screen 19 has cast upon it a series of images which are moved at a high speed upwards (or downwards, according to the direction of rotation of the shafts 7 and 8), and if a light-sensitive cell were substituted for this screen, it could be moved slowly across the moving image to produce the desired exploration of the whole image. This relative lateral movement between the series of images and the light-sensitive cell is preferably effected by means of a separate disc, 20, which is mounted on a shaft, 22, situated above the plane containing the shafts 7 and 8, so that the disc 20 overlaps the optical axis, 18, of the apparatus, as shown in Fig. 21.

The disc 20 carries a series of lenses, 21, which are moved across the optical axis (by virtue of the above-described disposition of the shafts) in a direction at right angles to the

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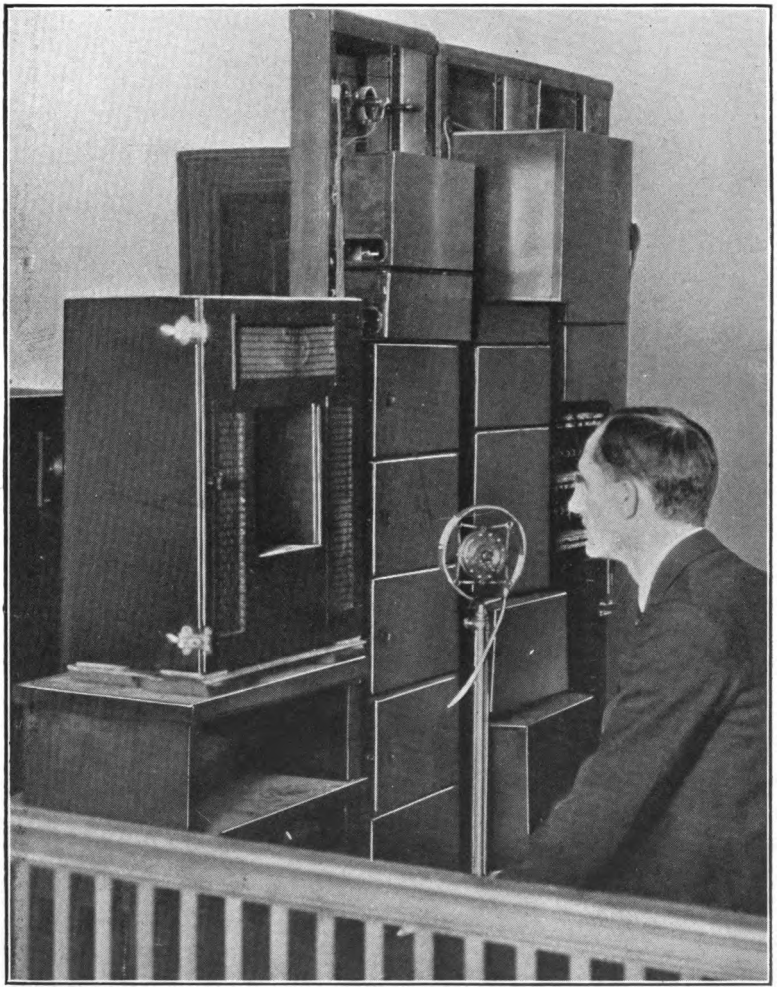

[*Photo courtesy American Telephone & Telegraph Co.*

THE TRANSMITTING APPARATUS OF THE AMERICAN TELEPHONE & TELEGRAPH CO.

The exploring beam of light from the scanning disc issues from the central opening of the box in front of the sitter. Light reflected back from his face strikes three large photoelectric cells situated behind the grills. The microphone picks up the sitter's speech. See Chapter VIII.



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direction of motion of the lenses 14 and 17. The shaft 22 may be rotated slowly compared with the shafts 7 and 8, thus causing the images to move laterally across the light-sensitive cell, so as to provide an adequately finely grained picture. The light-sensitive cell, 23, is situated on the optical axis of the apparatus.

The lateral movement of the series of images may be effected in any other desired manner. Thus, for example, the lenses on one of the discs could be arranged in a spiral, as shown on the disc, 1, in Fig. 20, instead of in a circle, so that each of the succession of images produced by the lenses of that disc are displaced slightly to one side of the previous image.

Quoting again from the patent specification: "To obtain increase of speed of traversal of the image a stationary bank of adjacent lenses may be used, say three, one above the other, between the object and the first disc, each lens casting an image of the object or view being transmitted on to a ground-glass screen, where the three images adjoin, one above the other. As the lenses are adjacent the three images will be almost identical. An image of this screen is then made to traverse a light-sensitive cell by any of the means herein described, and by the use of three lenses the speed is trebled.

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" The lenses may be arranged to work with more than one cell. For example, three vertical banks of three fixed lenses each might be used casting three vertical rows of three images on the screen, each of these rows operating its own cell, which would control its own light source at the receiving station, the light source replacing the cell behind an optical device similar to that at the transmitting station."

It will readily be appreciated that, with apparatus available which will cause light impulses to fall on the light-sensitive cell at any speed, the total number of impulses per second which the cell may be called upon to handle soon becomes enormous. Even if the cell is capable of responding at the chosen speed of operation, there still remains to be considered the medium of transmission. As we shall see in a later chapter, there are limitations to the speed at which signalling can be carried out, i.e. to the number of impulses per second which can be sent over the circuit connecting the transmitter to the receiver.

The difficulty of the response of the cell can be overcome by using more than one cell, and in his Patent No. 253,957 Baird describes methods of causing each cell to deal with its own band of the picture, and control its own light source at the receiver, where each light

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source reproduces the section of the picture dealt with at the transmitter by the cell which controls it. The signals, in this case, are sent along separate lines, or on separate wave-lengths, if wireless transmission is used.

If the transmission medium will handle

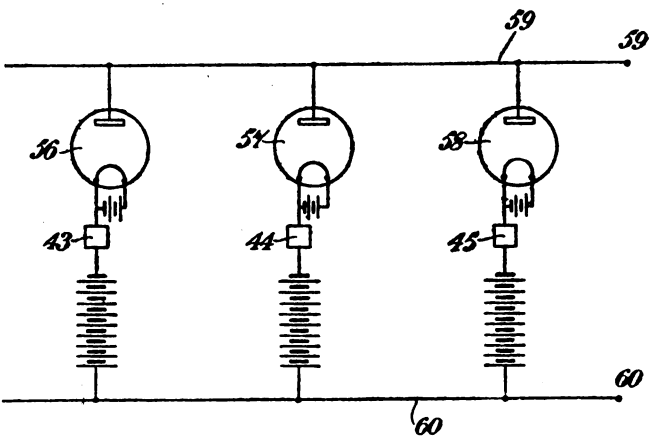


FIG. 22.—THE ARRANGEMENT OF MULTIPLE LIGHT-SENSITIVE CELLS AND ASSOCIATED 2-ELECTRODE NON-RETURN VALVES.

impulses at the required speed, however, there is no reason why the outputs of the light-sensitive cells should not all be transmitted over the same circuit, the output impulses of each cell being timed electrically to follow those of the preceding cell in the series, all in proper order. By the use of appropriate signal-accepting circuits at the

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receiver, the incoming impulses could be sorted out and applied to their proper light sources.

In cases where more than one light-sensitive cell is employed, each cell should be provided with its own amplifier. If the cells are connected in parallel and then fed to a single amplifier, they will tend to feed back through each other, causing a partial short-circuit. Even after individual amplification, it is advisable, as described in the last-mentioned patent, to place a 2-electrode valve in the output circuit of each amplifier to prevent feed-back. Alternatively, a 2-electrode valve can be placed in the output circuit of each cell direct, whereupon the output circuits of the three 2-electrode valves can safely be connected in parallel to a single amplifier.

This latter arrangement is shown in Fig. 22 (which is reproduced from the patent specification), where 43, 44, and 45 are the light-sensitive cells; 56, 57, and 58 are the 2-electrode valves; and 59 and 60 are the output terminals which are connected to the input terminals of the amplifier.

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# CHAPTER VIII

## THE AMERICAN TELEPHONE & TELEGRAPH COMPANY'S DEMONSTRATION. THE LIGHT-SPOT SYSTEM

AMONGST the latest experimenters to enter the television field are a group of engineers associated with the great American Telephone & Telegraph Company, one of America's largest industrial concerns, which depends for its scientific progress upon vast organised laboratories staffed by some of the cleverest telephone and telegraph engineers in the world.

A group of engineers attached to these laboratories (The Bell Telephone Laboratories, Inc.), after working on the problem for several years, succeeded, on April 7th, 1927, in giving a public demonstration of television over a wire circuit between Washington and New York; and over a wireless circuit between Whippany, N.J., and New York.

This demonstration was given before a party of guests which included business executives, newspaper editors, engineers, and



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scientists. The party assembled at the Bell Telephone Laboratories in New York, and were enabled to speak to, and simultaneously see, friends over the ordinary long-distance telephone line in Washington, 200 miles away.

Walter S. Gifford, President of the American Telephone & Telegraph Co., held a conversation with Secretary Hoover, of the U.S. Department of Commerce, who was in Washington. Mr. Hoover's remarks were made audible to the assembled guests in New York by means of a loud speaker, whilst the image of his face was made visible on two screens, one a small one for individual use, measuring about two and a half inches square, the other a large one measuring about two feet by three feet.

This large screen, which was prepared for the benefit of the visitors, appeared to be somewhat corrugated. This was due to the fact that the squares which made up the picture were arranged in fifty rows, one on top of the other. As the eye became accustomed to looking at the screen in the darkened room the image of the distant speaker's face was recognisable, although the features, which showed up clearly and sharply on the small screen, were considerably blurred by the enlargement, and at times disappeared altogether.

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It was plain that, enlarged to the size of an ordinary motion-picture screen, the de.. .. would have been completely lost. It was stated at the demonstration, however, that the invention was far from the picture-house stage of perfection.

The images reproduced on the small screen were fairly clear, however, and were described by witnesses as being comparable to faded daguerreotypes held in a shaky hand. In these small pictures the detail of the face appeared in black lines against a shining gold background, which latter was due to the orange light from the neon tube which was used to illuminate the small screen.

Following the wire demonstration between New York and Washington, the visitors were entertained to a repetition of the experiments, the transmission on this occasion being by wireless from the Company's experimental station, 3XN, at Whippany, N.J., about thirty miles from New York. An important feature of the demonstrations was that there was no difference in the quality of the reproduced image, whether it was transmitted from one end of the laboratory to the other, by wire from Washington, or by wireless from Whippany.

The engineers responsible for these demonstrations made it quite clear that their apparatus and methods could not yet be brought

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into regular commercial use. The necessary equipment was extremely elaborate and costly, and for the purpose of the public demonstration the services of a total of nearly 1,000 men were required!

Furthermore, the transmission of television, as achieved by the A. T. & T., required the use of a large group of frequencies, and the transmission of these frequencies required a considerable number of telephone circuits.

In the case of the wireless transmissions, one wave-length had to be used for sending the picture impulses, one for the synchronising impulses, and a third for speech, as shown in Fig. 23. In view of the already seriously congested state of the ether, this presents a formidable difficulty.

It is stated that much of the knowledge used by the engineers responsible for the development of the system of television under review was gained by them during the course of years of development and research, as a result of which the A. T. & T. now operates on a commercial basis a system of picture transmission by wire which covers the entire United States.

Television and phototelegraphy, either by wire or wireless, have several points in common, or at least closely associated, so that the engineers who developed the phototelegraphy

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[*Photo courtesy American Telephone & Telegraph Co.*

THE LARGE VIEWING SCREEN (IN AN UNFINISHED STATE) EMPLOYED BY THE AMERICAN TELEPHONE & TELEGRAPH CO.

It consists of a very long neon tube bent to and fro, and contains 2,500 electrodes. The mode of operation is described on page 105.



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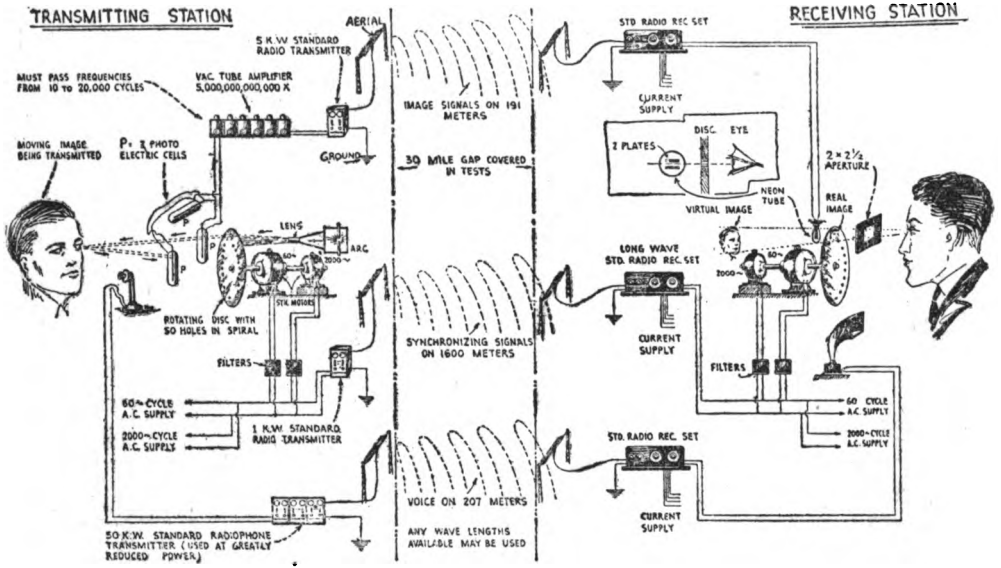




**Fig. 23.—A Comprehensive Diagram of the Entire Radio Television Apparatus.**

The subject, an image of whose face is being transmitted by radio, appears at the left, while the person observing the transmitted and reproduced image appears at the right. The perforated disc causes rapidly moving spots of light to sweep across the face; the reflections fall on photoelectric cells, P. The light fluctuations are thus transformed into minute electric currents, and these are amplified 5,000,000,000,000 times. The radio image signals are picked up by a standard receiving set, and after amplification, the image signals pass into a neon glow-tube placed behind a second revolving disc, driven in exact synchronism with that at the transmitter. The observer looking through the small aperture sees the image built up on a plane behind the whirling disc. The voice is transmitted and received in the usual manner; while a third radio wave transmits synchronising signals for the motors. A lens between the rotating disc of the receiver and the aperture has been omitted.

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system were able to make use of much of the information they had gained.

An essential feature of all television transmitters is that the scene to be transmitted must be illuminated. The intensity of the illumination depends largely upon the sensitivity of the light-sensitive device used to transform the light impulses into electrical impulses.

With all systems so far developed (with the exception of one of Baird's most recent developments), it has been customary to flood the entire scene with light, and this light, in most cases, has had to be so intense as to cause considerable discomfort to any person facing it.

The intensity of the light has had to be made so great because, when a photoelectric cell of the alkali type is used as the light-sensitive device, its response to light impulses is extremely feeble, the output requiring enormous amplification before it will perform the work required of it.

It must be borne in mind that the light which reaches the cell is *reflected* light, and some idea of the feebleness of reflected light may be obtained from the fact that if a human face be illuminated with a 1,000-c.p. lamp, placed at a distance of three feet, the total amount of light reflected back from it will scarcely amount to *one* candle power.

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In the matter of intense illumination, the television apparatus under consideration is no exception. Photoelectric cells were used to transform the light impulses into electric currents, and a very intense illumination was employed, this being provided by a Sperry arc consuming 40 amperes.

Between the arc and the scene there was interposed a revolving steel disc which had holes drilled in it near the circumference in the form of a single spiral. Through these holes there shone, at any given moment, only one single spot of light (see Fig. 23).

The rotary action of the disc caused this spot of light to travel from left to right across the scene or individual to be transmitted; then the next hole, set a trifle nearer the centre of the disc, allowed another spot of light to pass through, which travelled across the scene on a parallel track, but a trifle lower down than did the last one. As the disc continued to revolve, this action continued until the entire scene had been covered, or explored.

The disc revolved so rapidly that the whole scene or object was lighted up, a little spot at a time, in less than a fifteenth of a second. There were fifty holes in the discs used, so that the scene had fifty illuminated lines traced across it.

By this method an intense illumination

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of the sitter was obtained without its being unbearable. All that could be seen was a flickering spot of light which crossed and recrossed the sitter's face at an incredible speed. Even when using this method of illumination, however, it was said that the sitter began to feel a sensation of discomfort after a few minutes' exposure to the intense light spot.

In passing, it is interesting to note that Mr. J. L. Baird, the British inventor, used this light-spot method in the course of some of his original experiments, the method being described by him in his British Patent No. 269,658, of Jan. 27th, 1926, nearly eighteen months previous to the A. T. & T. demonstration. The system is illustrated diagrammatically in Fig. 24. Baird has recently developed the method still further, adding many refinements; but the system has its obvious limitations, owing to the restricted field of view which it is possible to cover with a travelling light spot.

The lines, contours, and colours of the sitter's face cause variations in the degree of brilliancy of the spots of light which they reflect, and these, in turn, cause a similarly varying effect when they strike the photo-electric cells.

In the A. T. & T. apparatus, the person to be televised sat before a box-like instrument,

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[*Photo courtesy General Electric Co., U.S.A.*

THE TRANSMITTING APPARATUS EMPLOYED BY THE GENERAL ELECTRIC COMPANY (U.S.A.).

On the extreme left is the light source, in front of which revolves the scanning disc. A moving pencil of light passes through the lens and traverses the face of the sitter. The three rounded objects in front of the sitter are the photoelectric cells.



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from a cavity in the centre of which the light spot issued, illuminating his face. Around this cavity, on both sides and on the top, were placed three huge photoelectric cells. These cells measured about 16 inches long, and are probably the largest ever made.

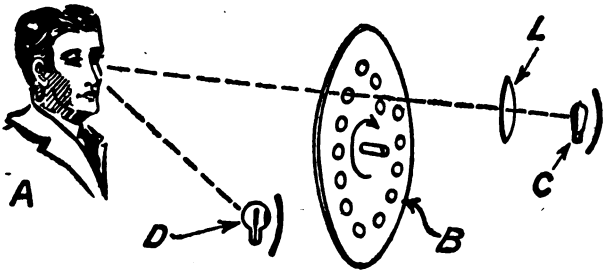


FIG. 24.—BAIRD'S LIGHT-SPOT SYSTEM.

A beam of light from the source C shines through lens L and the spiral of holes in disc B on to the object A to be transmitted. Light reflected back from A shines on to the light-sensitive cell, D. The rotary action of the disc causes the light spot to move continuously to and fro across A in parallel lines at a very rapid rate. In this way the entire object is explored and flashes of light from every portion of it are thrown, in regular order, on to the cell, D.

Light reflected from the sitter's face fell upon these cells, the electrical response of which, after amplification, was sent to the receiver. As already explained in a previous chapter, the output of a photoelectric cell is very feeble. Hence the use of such huge cells, and the use of three of them in parallel, instead of only one.

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Notwithstanding this arrangement, the amplification of the output current had to be enormous. In the case of the radio transmissions from Whippany, for example, it was estimated that the photoelectric current was amplified 5,000 million million times before it reached the transmitting aerial! This amplification, of course, included the power amplification of the wireless transmitter itself.

As each detail of the sitter was illuminated, the photoelectric cells instantly responded, initiating a current proportional to the light reflected back on to them; and hence proportional to the light and shade of the particular detail. As the light spot swung across the scene, working its way to and fro and from top to bottom, the current from the cells varied correspondingly.

So swiftly did the beam sweep the scene that the current variations were wide and rapid—sometimes corresponding to a change from a maximum to a minimum in a twenty-thousandth of a second. These variations, the so-called alternating current components, comprised the electrical impulses which were transmitted to the distant receiver. The speed of signalling was therefore about 20,000 per second.

As already mentioned, two forms of receiving apparatus were used at the demonstra-

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tion. In each form a neon gas tube was an important element. Such tubes, as has been explained in a previous chapter, are hollow glass vessels in which the air has been replaced by neon gas at a very low pressure. Electrical discharges passing through such a tube cause it to glow, the brilliance of the light being directly proportional to the strength of the current.

It will at once be appreciated that, in regard to the relation between light and electricity, the properties of a neon gas tube are exactly opposite to those of a photo-electric cell.

In the A. T. & T. apparatus for use by an individual, a small neon tube was used, the entire tube being caused to glow in accordance with the strength of the current being received from the transmitting station at any particular instant.

Between the tube and the observer, who looked through a small aperture about two and a half inches square, there was interposed a disc exactly similar to the one at the transmitter, rotating in step with it. The result was that the observer saw at successive instants successive portions of the field of view, each of which was illuminated by the glowing neon tube.

So rapidly was the scanning of the field of vision carried out that the observer's

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sensation was that of seeing the scene as a whole repeated just as it appeared at the transmitter.

Had the mechanism suddenly stopped dead, what the observer would have seen would have been a tiny spot of light, admitted to his line of vision through one of the holes of the disc, and constantly fluctuating in intensity. The rotary action of the disc spreads, as it were, the light-spot fluctuations all over the receiving screen, each light or dark spot of illumination being in its exact place to correspond with the scene being transmitted.

For the presentation of the image to a large audience a different method was employed experimentally. This particular method was also used some time ago by Mr. Baird, and is described by him in his Patent No. 222,604, July 1924.

Instead of using a single relatively small neon tube, successive portions of which are viewed at successive intervals, a very long tube was used, which was folded back and forth upon itself to form a grid, as shown in Fig. 25, which illustrates the arrangement diagrammatically.

The tube was bent into fifty loops, corresponding with the number of holes in the scanning disc at the transmitter. Instead of fitting this long tube with a single pair of

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THE EXPERIMENTAL WIRELESS TRANSMITTER ON THE ROOF OF THE BAIRD LABORATORIES. CALL SIGN, 2TV.



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electrodes, like the smaller tube, the grid was equipped with 2,500 electrodes, fifty per turn of the loop. Each electrode then corresponded to a single elemental area of the picture plane which was scanned by the photo-electric cells at the sending end.

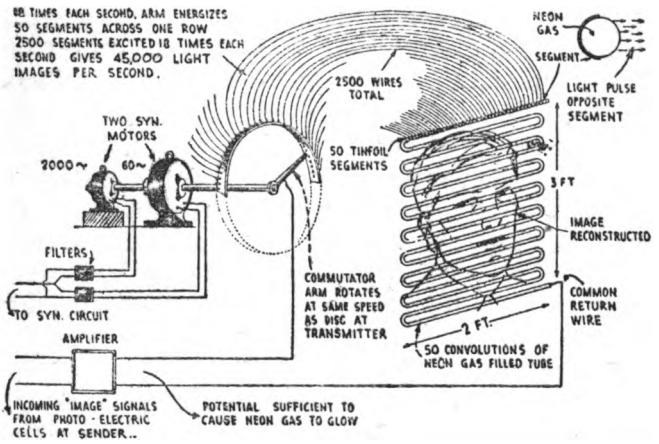


FIG. 25.—THE LARGE EXHIBITION SCREEN, BUILT UP OF A CONTINUOUS LENGTH OF GLASS TUBING, ALONG THE REAR WALLS OF WHICH ARE CEMENTED 2,500 TIN-FOIL SEGMENTS.

The tube is filled with neon gas; light spots appear opposite each segment when electrically energised.

These electrodes were connected by wires to a distributor which, in turn, was connected to the circuit coming from the transmitting station. The distributor, which was a form of commutator, revolved in exact synchronism with the scanning disc at the sending end.

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When a particular spot on the object being televised was illuminated, its position and light intensity were transmitted, in the form of an electrical impulse, to the receiving station, as has already been described. In this case, however, the distributor selected the proper connection with the neon tube grid and lighted a spot on it which corresponded with the spot on the original scene, the illumination of which set up the impulse in the first place.

Only one spot on the grid was illuminated at a time, but these glowing spots followed each other with such rapidity that the audience appeared to see the entire grid lighted up continuously, in the form of the scene at the transmitter. The grid was arranged so that it could be viewed either directly, or through a ground-glass screen, to soften the "grain" somewhat.

The distributor consisted of a brush contact which revolved in synchronism with the scanning disc at the sending end. This brush, as it revolved, made contact with a commutator arrangement, composed of 2,500 segments, to which the leads to the neon tube electrodes were connected.

Each segment picked up from the rotating brush the appropriate electrical impulse intended for it, and conducted it over the connecting wire to the appropriate electrode on the grid. To each of the 2,500 electrodes 15

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impulses per second had to be delivered, so it will readily be appreciated that the most minute error would have hopelessly scrambled the picture. How the mechanisms were kept in step is described in the chapter devoted to synchronism.

This arrangement of a long neon tube and distributor, although it has been tried experimentally both by Mr. Baird and by the A. T. & T., is, of course, hopelessly impractical for regular commercial operation, owing to the maze of connecting wires required, and the delicacy of adjustment of the apparatus. The whole arrangement is, in fact, very reminiscent of the experimental apparatus built by Rignoux and Fournier in 1906.

From a purely experimental point of view, however, the apparatus is highly interesting, and it has proved its ability to perform in the manner required.

In January, 1928, the General Electric Company of America gave a demonstration of television on lines almost identical with those which have just been described. They used the same light-spot method previously described and used by Baird and the A. T. & T. Co.

Transmission took place by wireless from one of the company's short-wave stations at Schenectady, N.Y., on 37·8 metres, while the ordinary medium-wave broadcasting station,

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WGY, operating on 378·9 metres, sent out the speech and music produced by those whose images were being televised.

At four separate homes within a few miles of Schenectady, television receivers and broadcast receivers were installed, the object of the demonstration being an endeavour to show that the day of the home televisor is not far distant.

No attempt was made automatically to synchronise the receiving televisors with the transmitting mechanism, the object of the omission of all synchronising mechanisms being to simplify the device.

At the receiving stations, ordinary direct current motors were used to drive the revolving discs, and the speed of these motors was controlled manually, the operator watching the image and keeping the speed constant by means of a hand-controlled regulator.

D.C. motors have a habit of "hunting," which will be described more fully in the next chapter; but it is possible to keep them at a fairly constant speed by expert hand regulation. The operation, however, partakes of the nature of a feat of juggling, and simply begs the whole question of synchronism. Even with the most expert manipulation the picture cannot be kept steady for longer than very brief intervals.

There was no feature of novel interest in

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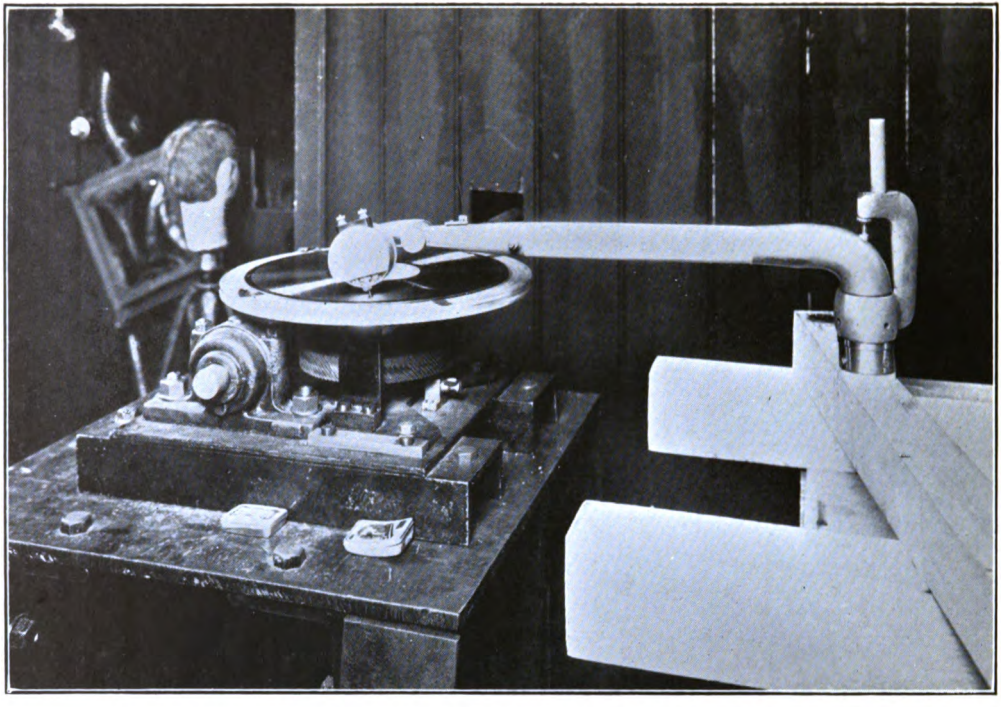

THE BAIRD EXPERIMENTAL PHONOVISION RECORDING APPARATUS.

Image sounds can be recorded on an ordinary master record and later turned back into visible and recognisable images. See Chapter XII.



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the apparatus employed by the General Electric Company at this demonstration. It has served, however, to render all the more significant the fact that the only television systems which have given results up to the present are worked along lines identical with those first disclosed by Baird and demonstrated by him in this country.

Another significant feature is the fact that the G.E.C. have, for the time being at least, abandoned, in favour of the neon tube light source, a system of projection outlined by them last year.

In this system it was proposed to use a seven light spot arc lamp projector, the brilliancy of the light spots to be controlled, before projection on to the receiving screen, by means of shutters controlled, in turn, by seven separate photoelectric cells at the distant transmitter. This, of course, entailed the use of seven separate transmission channels, either wire or wireless. To cause the seven light spots to move together to and fro across the screen it was proposed to use a revolving mirror polyhedron.

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# CHAPTER IX

## METHODS OF SYNCHRONISM

ONE of the greatest problems in connection with television is that of securing and maintaining synchronism between the transmitting and receiving mechanisms.

In phototelegraphy, as distinct from television, the problem is relatively simple of solution, for the speed of transmission is so very much slower. Also, as will be made clearer later, synchronism in phototelegraphy need only be carried out in what might be described as a single dimension, as far as the automatic mechanism is concerned; whereas, in television, it must be carried out, in a sense, to two dimensions.

In most systems of phototelegraphy the problem resolves itself into the rotation at precisely equal speeds of two cylinders, one at the transmitter and one at the receiver. The recording device at the receiver can be set to the correct starting point by hand, and simultaneous starting of the two cylinders can be effected by some form of prearranged signal.



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The maintenance of equal speeds of operation of different mechanisms can be accomplished in several ways which have been devised from time to time for different purposes. The methods employed may be roughly divided into two classes, in one of which independent generators of a controlling current of constant frequency are used at both the transmitting and receiving stations. In the other class a constant frequency generated at the transmitter is sent to the receiver and applied there to control the speed of the mechanism.

Devices of the former class generally make use of electrically driven tuning-forks or clockwork-operated pendulums as the means of generating accurately timed impulses. For slow-speed work it is sufficient to arrange for a swinging pendulum to close a contact at the end of its swing, but for higher speed work, or for greater accuracy, it is better to make use of the more rapid impulses obtainable from a vibrating fork.

The general arrangement of an electrically operated tuning-fork is shown in Fig. 26. Current flowing through the windings of the electromagnet attracts the fork, pulling it over so that the interrupter contact is opened, thus switching off the current and permitting the fork to return to its normal position, when the contact once more closes and the fork is again

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attracted. The action is similar to that of a buzzer, only, in this case, the perfectly tuned fork sets up, in the battery circuit, an intermittent current the frequency of which corresponds exactly with the frequency of vibration of the fork.

Representative of the manner in which a fork can be applied to synchronise two remotely separated mechanisms is the system of synchronism developed by Captain R. H.

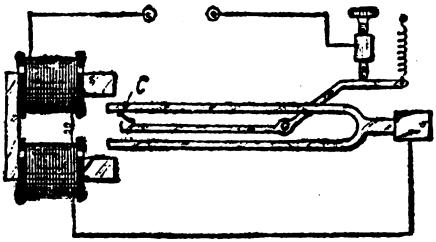


FIG. 26.—A FORM OF TUNING-FORK INTERRUPTER WHICH IS KEPT VIBRATING BY MEANS OF AN ELECTROMAGNET.

Ranger, of the Radio Corporation of America, and used in the transmission of photographs, facsimiles, etc., between London and New York, and between New York and Honolulu, by combined wire and wireless transmission. These transmissions, it should be clearly understood, constitute phototelegraphy, not television.

The circuit arrangements of the Ranger synchronising method are given in Fig. 27. The heart of the device is the electrically

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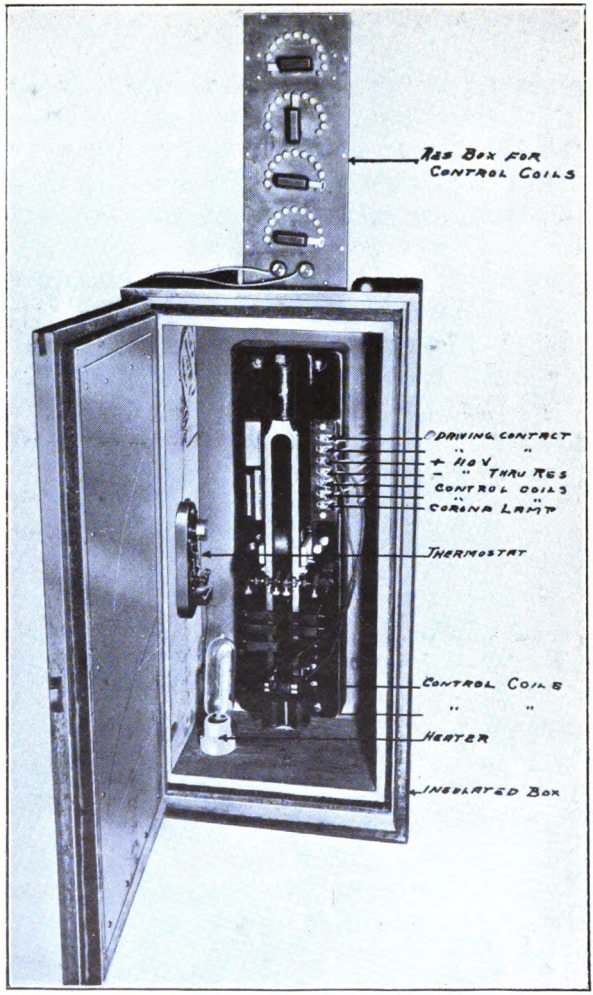


[*Photo courtesy Radio Corporation of America.*

THE SYNCHRONISING FORK EMPLOYED IN THE RANGER SYSTEM OF PHOTOTELEGRAPHY.

It is kept in a constant temperature box.



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operated tuning-fork, which is mounted in an insulated case. This case is kept heated to a constant temperature by means of a lamp. By keeping the temperature constant, variations in the frequency of vibration of

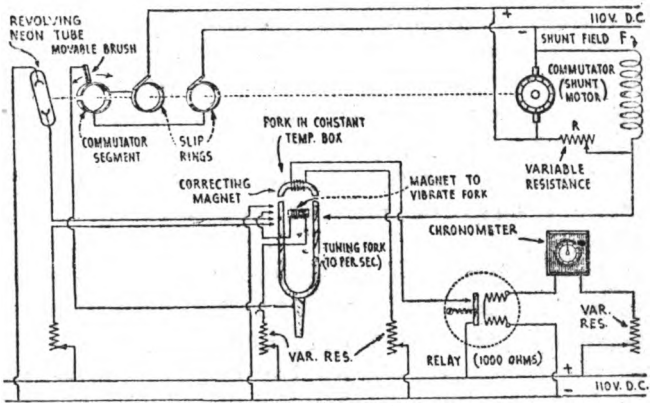


FIG. 27.—THIS DIAGRAM SHOWS THE INDEPENDENT AND SELF-CONTAINED FORM OF SYNCHRONOUS MOTOR DEVISED BY CAPT. R. H. RANGER, OF THE RADIO CORPORATION OF AMERICA, FOR HIS PICTURE TRANSMISSION MACHINES.

The shaft of the ordinary shunt-wound D.C. motor carries at one end a revolving neon tube. When the fork contacts are closed under certain conditions, the motor speed is increased or decreased, as explained in the text. The chronometer checks the tuning-fork once a second.

the fork, due to expansion and contraction of the metal at various temperatures, is avoided.

The tuning-fork is caused to vibrate at a frequency of 70 per second by means of the electromagnet and interrupter contacts shown, and a chronometer, operating through a relay



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and the correcting magnet, keeps the frequency of vibration constant.

In the upper right-hand corner of Fig. 27 is the D.C. shunt-wound motor which drives the photo-transmission mechanism, and the vibrating fork keeps its speed of rotation constant in the following manner.

If, at a given moment, all the tuning-fork and commutator contacts are closed, the variable resistance in series with the field winding of the motor is short-circuited and the speed of the motor is reduced, due to the sudden rush of current through the field winding.

At another moment it may be that the contacts are closed through the tuning-fork and auxiliary commutator segments and slip rings at the left-hand end of the motor shaft. In such a case the field winding of the motor will be short-circuited, and due to the greatly weakened field the speed of the motor will increase. This action goes on repeatedly, so that the average speed of the motor remains constant.

The motor is designed to run at a speed of 2,100 revolutions per minute. In order to check the synchronism a neon tube is fitted on to the end of the motor shaft, and revolves with it. This tube receives an impulse for each vibration of the fork, i.e. 70 per second, or 4,200 per minute. The tube therefore

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receives two impulses for each revolution of the motor shaft. The result, to the observer, is a stroboscope effect.

That is to say, if the motor is revolving in perfect synchronism with the tuning-fork, the neon tube appears to be stationary. If the speed is below synchronism, the neon tube will appear to be turning slowly backwards, like the wheels of a motor-car often appear to be on the cinematograph screen. If the motor speed is above synchronism, then the neon tube will appear to turn slowly forward.

Exactly similar driving motors and tuning-forks are supplied to the transmitting and receiving stations, particular care being taken over the tuning of the fork, so that the transmitting and receiving mechanisms are certain to revolve at the same speed, i.e. in synchronism.

This method, although eminently satisfactory for phototelegraphy, is not suitable for television, for it is rather complicated, and with the greatly increased speed of transmission involved in television the degree of synchronism obtainable is not sufficiently great.

The other class of synchronising method, in which the synchronism of the receiver mechanism is under the direct control of a constant frequency generator at the transmitter, involves the transmission to the

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receiver of the constant frequency current, and the use of a control mechanism at the receiver which is capable of being operated at a speed which is dependent solely and absolutely on the frequency of the incoming current impulses.

It matters little what form of constant frequency generator is employed at the transmitter, so long as the generated frequency is sufficiently high. It may be an electrically operated tuning-fork, or a valve oscillator controlled by a tuning-fork or a quartz crystal; or it may be a small alternating current dynamo coupled to the shaft of the main driving motor of the transmitter.

At the receiver it is usual to cause the incoming constant frequency current to drive a small synchronous motor which is coupled to the shaft of the main receiver driving motor. Synchronous motors consist essentially of an armature, or rotor, supplied with an alternating current; and a stator supplied with direct current. In an even simpler form, such as that shown in Fig. 28, the alternating current is fed to the stator, and the rotor may be either a wooden drum with longitudinal iron strips, or an iron wheel with teeth cut out of its periphery. Each A.C. impulse energises the stator magnets and pulls the rotor round, due to the attraction between the magnets and the teeth or strips of the rotor.

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The speed at which such motors run is entirely dependent upon the periodicity, or frequency, of the alternating current supply, and upon the number of poles present in the rotor or stator, whichever is receiving the A.C. It follows, therefore, that if the periodicity of the A.C. supply is absolutely constant, the speed of rotation of the synchronous motor is also constant. Furthermore, if such a

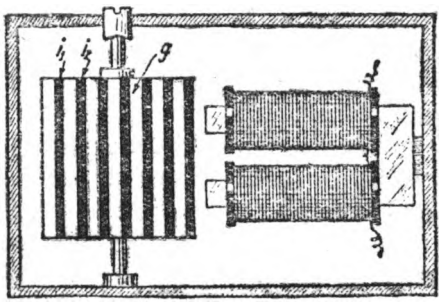


FIG. 28.—THE SIMPLEST FORM OF SYNCHRONOUS MOTOR, SOMETIMES CALLED A PHONIC DRUM.

motor is coupled to another motor which is inclined (if left to itself) to vary in speed slightly, the synchronous motor will keep the second motor running at a constant speed also.

Thus, by generating a constant frequency current at the transmitter, causing part of it to control the speed of rotation of the transmitter mechanism, and sending part of it

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over a circuit to the receiver, there to drive a synchronous motor, the receiving mechanism can be kept running at exactly the same speed as that at the transmitter.

The above method gives more accurate control over the two mechanisms than does the previous method of independent control. In the latter method, absolute constancy of the frequency of the controlling current is a *sine qua non.* In the former method, constancy is not a first requisite, for whatever variations affect the transmitter, they affect the receiver in like degree and absolutely in unison.

The system can thus be simplified by dispensing with an elaborate constant frequency generator. In place of it, a small A.C. dynamo can be mechanically coupled to the shaft of the motor which drives the transmitting mechanism, the generated current being sent to the receiver, there to drive the synchronous motor. It then follows that if the transmitter motor varies in speed, the frequency of the output of the A.C. generator will vary, which in turn will cause the speed of the synchronous motor and the receiver driving motor coupled to it to vary. The fact that they do vary does not matter, for *they vary in exact unison,* and synchronism is still preserved.

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# CHAPTER X

## METHODS OF SYNCHRONISM (*continued*)

IF the transmitting and receiving mechanisms of a phototelegraphy system are not running in synchronism, distortion of the received image is the result. If, throughout the transmission, the receiving mechanism is running consistently faster or slower than the transmitter, the received picture, instead of being square in outline, will appear diamond shaped, and all the details of it will be twisted.

If the receiving mechanism is running at times faster, and at times slower, the distortion will be even worse, and may easily render the picture completely unrecognisable. A similar wavy effect could be produced on a wet photographic negative which has been immersed in warm water to soften the film, by running the finger alternately up and down it in parallel lines.

In phototelegraphy, given synchronism between the transmitter and receiver, the two mechanisms can be stopped at the end of the transmission of a picture, and simultaneously



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restarted for the transmission of the next, thus ensuring that both mechanisms begin at the proper starting point, in step with each other.

In television, however, both mechanisms are running continuously, transmitting and receiving, one after another, sixteen complete pictures per second. Under these conditions it is possible for both mechanisms to be running at the same speed and still the image may be incorrectly received at the distant receiver.

This difficulty has given rise to a common misunderstanding, prevalent even in technical circles, which, in turn, has caused the difficulty of synchronism in television to be, to some extent, overrated.

It has often been stated that a difference of phase of only 1 per cent. between the transmitter and receiver is sufficient to spoil the definition of the received image. Were such a statement correct the problem of synchronism would indeed be one of immense difficulty.

Fortunately, however, an analysis of the facts shows that if the transmitting and receiving mechanisms are out of phase the image is not blurred, but merely displaced. The definition remains unaffected. The effect is as if the image of a man's face, instead of being visible squarely in the centre of the receiving screen, were displaced to right or left, so that his face appeared to be cut off

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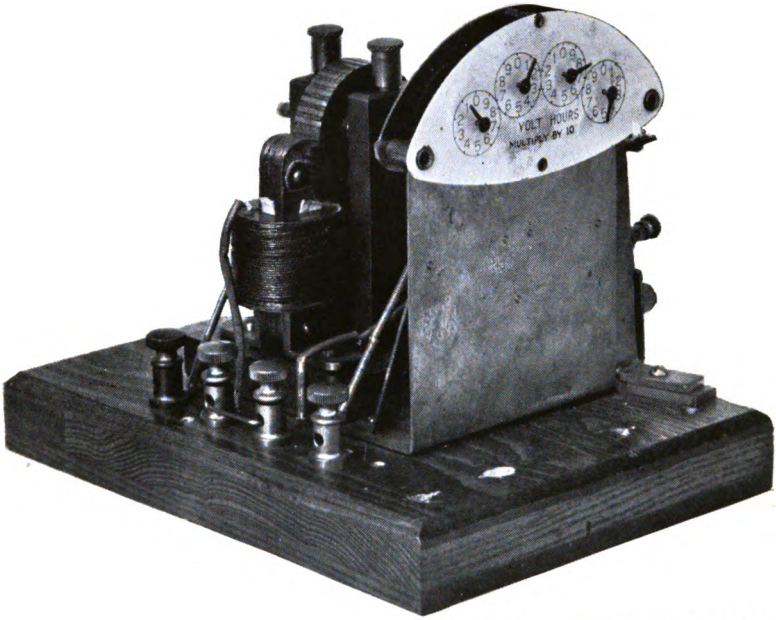


[*Photo courtesy General Electric Co., U.S.A.*

A SIMPLE FORM OF SYNCHRONOUS MOTOR.



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vertically, say, by the nose. On the other side of the screen the other half of his face would then be visible, also cut off by the nose. In the centre of the screen his right and left ears would be almost touching each other.

In phototelegraphy a similar effect would be obtained if, on starting the transmitting cylinder at the beginning of a picture, the receiving stylus were set, not at the commencing end of the cylinder, but somewhere in the middle. If, when the recording stylus reached the end of the cylinder it were to be lifted and set at the other end of it, the correct starting point, the result would be that the left half of the face would be on the right-hand side of the picture, and *vice versa*.

This difficulty cannot arise in phototelegraphy, except through carelessness, for the correct starting point is arranged first by hand before starting up. In television, with continuously running mechanisms handling sixteen complete pictures per second, it is not possible to arrange the starting point correctly by hand; some electrical or mechanical means of doing the job must be found. This is what was meant when it was stated that, in television, synchronism must be carried out, in a sense, to two dimensions.

The distortion, or blurring of a television image is caused only by different speeds prevailing at the transmitter and receiver;

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that is to say, by lack of *isochronism*. Two mechanisms may be in isochronism, and yet not be in synchronism ; and as the distinction between the two expressions may not be familiar to many readers, it may be as well to define it.

When two machines are said to be running in isochronism, what is meant is that they are running at the same speed, but are out of step, just as two men's legs may be out of step although both are moving at the same speed and the feet of both strike the ground at the same instant. A similar case is that of two clocks which are both keeping perfect time, although the hands of one might point to 2.30 and the hands of the other to three o'clock. Isochronism has been achieved in both cases, but for synchronism to be achieved the two men would have to be what the army calls " in step " and the hands of both clocks would have to indicate exactly the same hour.

When the first efforts were made to achieve television, attempts were made to obtain isochronism by means of the methods used in phototelegraphy, briefly referred to in Chapter IX. Such methods, however, do not lend themselves to television, for, as already stated, they are either too complicated or insufficiently accurate, or both.

By using synchronous motors, however, perfect isochronism can readily be obtained,

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and the mechanical and electrical arrangements involved are not nearly so complicated. It was with the aid of such motors that the first successful demonstration of silhouette television by wireless was given by Baird in April 1925.

At first glance, it might be supposed that isochronism between two television mechanisms could be obtained by using two exactly similar motors controlled by rheostats and run at exactly the same speed, as indicated by some form of speedometer. This cannot be done, however, for ordinary electric motors continually vary slightly in speed, due to small variations in the supply current and other reasons. These variations occur too rapidly to be adequately corrected by a hand-controlled rheostat. This habit of variation is known as " hunting," and before television can successfully be achieved, the hunting propensities of at least one of the machines must be brought under exact control.

The main driving motor at the transmitter has this usual tendency to hunt ; and if the system of synchronism employed involves the use of an A.C. generator coupled to its shaft to produce the isochronism impulses, it may be allowed to hunt unchecked, for the periodicity of the generated A.C. varies in exact accordance with its speed wanderings.

On the other hand, the main driving motor

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at the receiver is not allowed to hunt independently. Its speed is under the cast-iron control of the synchronous motor coupled to it; and as the speed of the latter varies precisely in sympathy with the periodicity changes of the distant A.C. generator, it follows that the main receiver motor must at all times be revolving at exactly the same speed as the main transmitter motor. The fact that they both hunt slightly does not matter, for they hunt in unison. Therefore, isochronism is achieved.

There remains now the question of synchronism. That is to say, although we now have the two machines running at exactly the same speed, we have, as yet, no means for adjusting the mechanisms so that they run *in phase* with each other.

As stated earlier on, a difference of phase does not cause blurring of the image or loss of definition. It merely causes a shift of the image as a whole, and this image shift is very simply rectified by the expedient of rotating the receiver driving mechanism as a whole about its spindle until the picture comes into view in its proper place.

This rotating action is very similar to the method of adjusting the spark gap of an old-fashioned synchronous spark wireless transmitter. In the latter case, since the revolving electrodes were mechanically coupled to the

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shaft of the A.C. generator, the two were, of necessity, in isochronism at all times. The spark, however, might easily be out of phase, as indicated by an apparent violent oscillation back and forth of the revolving electrodes, as viewed end on. To bring the spark into phase, the fixed electrodes were simply rotated round the circumference of the revolving disc until synchronism was indicated by the disc appearing to stand still.

The phasing of a television image may also be compared to the action performed by a cinematograph projector operator when the picture appears on the screen with the actors' feet at the top of the screen and their heads at the bottom, with a dividing line across the middle. All that is required is a simple adjustment to " frame " the picture properly.

In Fig. 29 a cross-sectional view is given of a television receiver driving mechanism. At the extreme right-hand end of the shaft is the scanning disc. Farther to the left, within the carcase, is the main driving motor, which may be supplied with either D.C. or A.C., whichever is available. To the left of that is the synchronous motor which controls the speed of rotation of the main motor, giving isochronism.

The carcase of these motors is mounted on bearings, so that it can be rotated bodily by means of a handle operating through a worm

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gear. This feature is more clearly shown in Fig. 30.

It will be seen that this mechanism has the

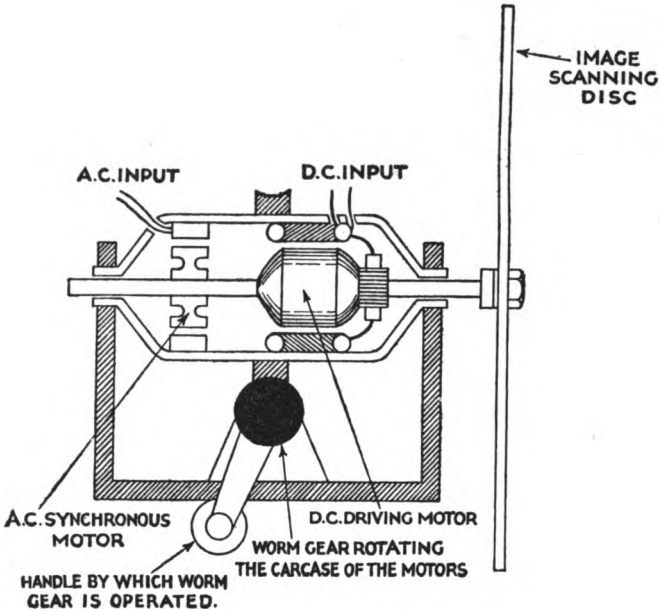


FIG. 29.—THE ARRANGEMENT OF THE RECEIVER MAIN DRIVING MOTOR AND SYNCHRONOUS CONTROL MOTOR.

Showing how the carcase of the motors is rotated by means of a handle operating through a worm gear to obtain synchronism.

merit of extreme simplicity, and it would appear to work extremely well in practice, for it is essentially the method used not only by Mr. Baird in this country, but also by the

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American Telephone & Telegraph Co. in their demonstration between Washington and New York.

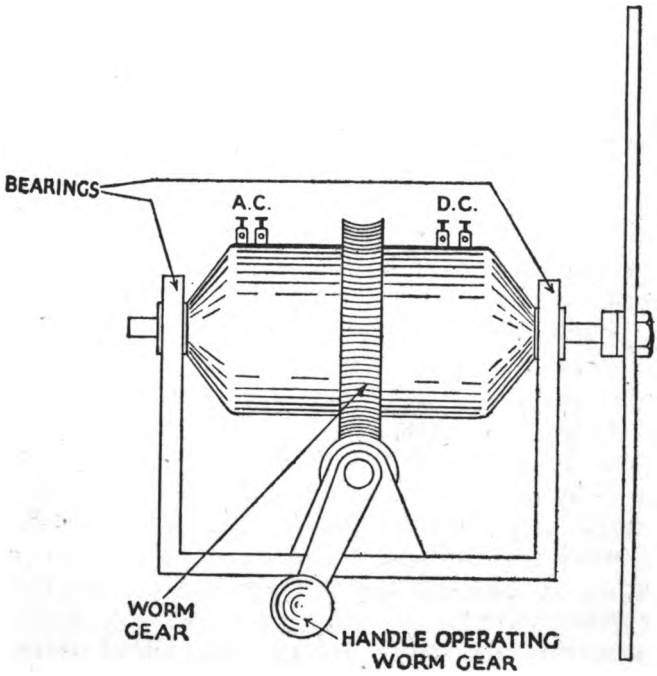


FIG. 30.—ANOTHER SKETCH OF THE SYNCHRONISING AND DRIVING MOTORS.

Mr. Baird's Patent No. 236,978 of 1924 describes this method of rotating the mechanism to obtain synchronism, and to him belongs the credit of being the first successfully to

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apply these synchronising principles to television.

In practice, after running up to speed both transmitting and receiving mechanisms, and thus automatically achieving isochronism (by virtue of the control exerted by the synchronous motor), all the operator has to do to achieve synchronism is to watch the received image on the screen, and turn the worm gear handle shown in Figs. 29 and 30 until the picture appears on the screen in its proper place; or in cinematograph parlance, until it is properly "framed."

There remains the question of the transmission to the receiver of the A.C. synchronising current generated at the transmitter.

It is, of course, impossible at the present time to transmit power by wireless, or over a telephone line. Therefore, some means must be provided whereby the A.C. can be caused to influence the receiver. This is done by causing the A.C. to modulate the carrier current, in the case of wire communication between two points, or the carrier wave, in the case of wireless communication.

This modulation, of course, takes the form of a continuous note of audible frequency, corresponding to the periodicity of the generator output. The American Telephone & Telegraph Co., when they gave their demonstration, used a separate channel for

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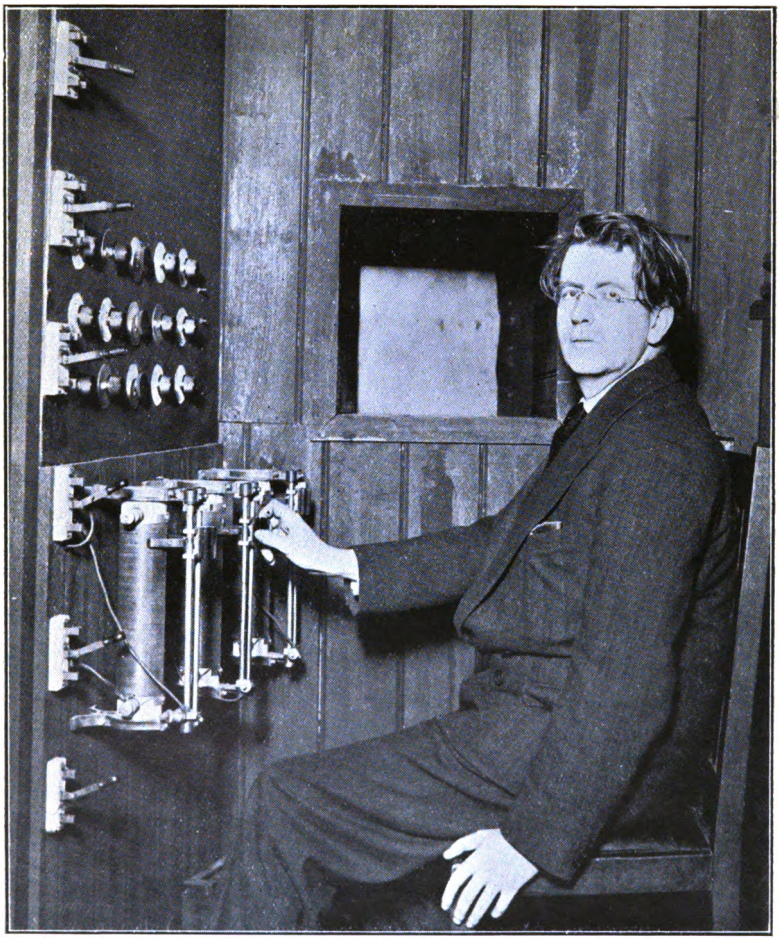

J. L. BAIRD PHOTOGRAPHED BEFORE THE PILOT IMAGE SCREEN, AND AT THE CONTROLS OF THE MACHINE USED TO TRANSMIT TELEVISION ACROSS THE ATLANTIC, AND TO THE *BERENGARIA*.

This particular machine re-produced on the pilot screen an image of a human head which was life-size, without the use of magnifying lenses.



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the synchronising frequency. At the receiving station the synchronising note, after amplification by means of valve amplifiers, is fed to the synchronous motor.

To make the entire subject clear to the reader, we will describe the exact apparatus and methods used on the occasion of Mr. Baird's first public demonstration of television, in April 1925. At this demonstration, which was an early effort with crude apparatus, outlines were shown; and two separate channels were used, one for the television impulses, and one for the synchronising impulses. However, the method employed was essentially the same as that described above.

The transmitter was connected to two small frame aerials, one of which transmitted the television signals, while the other transmitted the note caused by the A.C. generator. At the receiving station, which was at the other end of the same room, two similar frame aerials were employed to pick up the two sets of impulses.

The synchronising note, after being picked up by the frame aerial and its associated tuning apparatus, was amplified by a 3-valve Mark IV amplifier, the output of which was connected to a Post Office relay. The amplified alternating current, therefore, caused the reed of the relay to make contact first in one direction and then in the opposite direction.



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That is to say, the reed was caused to oscillate, or vibrate, between the two fixed contacts set on either side of it. The output of the relay was therefore an alternating current, directly in phase with the A.C. generated at the transmitter.

In order to isochronise the two machines, the receiver driving motor was first run up to speed, under the rough control of a rheostat. The synchronous motor, of course, came up to speed as well, although, as yet, unsupplied with current. The input to the synchronous motor was controlled by means of a double pole switch, which connected it to the output of the relay. Across the contacts of the switch were connected two little lamps.

As the synchronous motor came up to speed, the lamps flickered, the flickering becoming less and less (i.e. diminishing in frequency) as the speed of the synchronous motor (and, of course, the main driving motor) approached that of the generator at the transmitter.

When the speeds became exactly isochronous the flickering ceased and the lamps went out entirely. At that moment the switch was closed and the current from the relay fed to the synchronous motor. This current was sufficient to prevent the synchronous motor creeping out of phase, which, in turn, prevented the receiver main driving motor from hunting independently of the transmitter motor.

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Isochronism having been achieved, synchronism was obtained, as already explained, by rotating the receiver motor bodily until the received image appeared in its proper place.

It will be understood, of course, that the synchronising current, even after amplification, is extremely small, but where well-balanced mechanisms are employed, only a very small synchronising current is necessary to keep them in step.

During the course of his original experiments, Baird used a synchronising frequency of 500 cycles, but the higher the frequency used, within limits, the more accurate is the degree of control. During their Washington–New York demonstration, the A. T. & T. used a synchronising frequency of 2,000, which is, perhaps, unnecessarily high, and adds to the difficulties of sending both television and synchronising impulses over the same circuit. At a frequency of 2,000, filtering becomes a somewhat dangerous method of separating the two sets of impulses, for some of the television impulses may easily extend in frequency below 2,000, and would thus be cut off entirely from the television part of the circuit, and, instead, be led into the synchronising part of the apparatus, there, perhaps, to cause trouble by interference.

It is understood that Baird has recently

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developed other synchronising methods by the use of which he has been able to dispense with a separate channel of communication. Details of this latest development are not available at the time of going to press, but it is believed that the new method is extremely simple, elaborate oscillating circuits not being required. Judging by results, which the author has been privileged to see, the system is remarkably effective, and apparently automatic in action.

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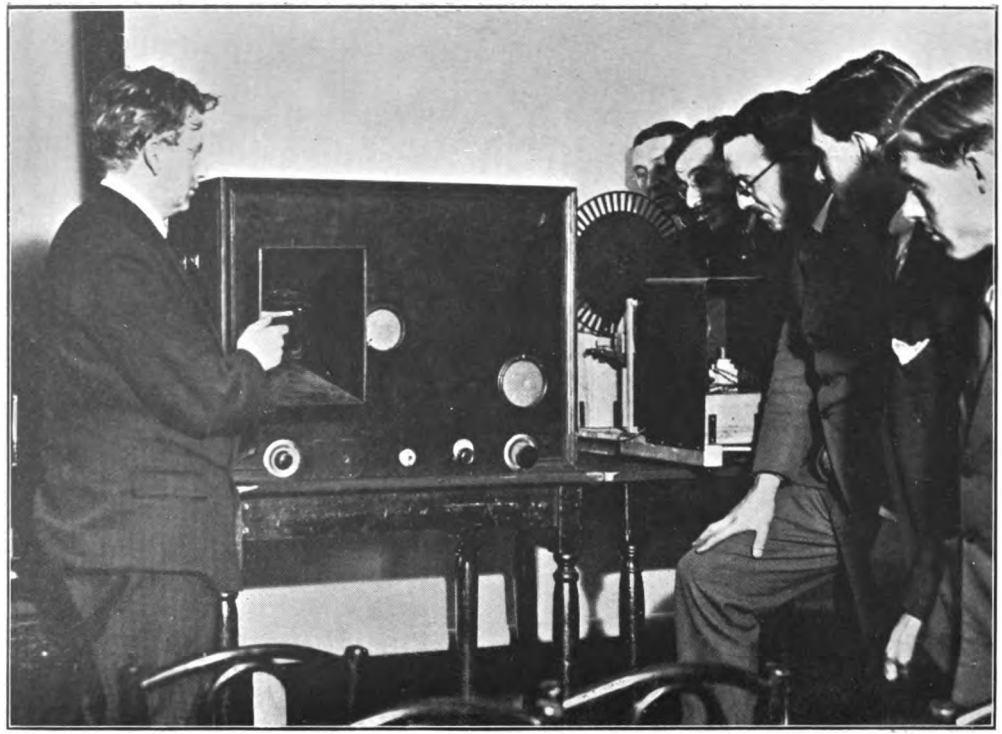

MR. BAIRD DEMONSTRATING BEFORE MEMBERS OF THE TELEVISION SOCIETY, ON MAY 1ST, 1928, THE ACTUAL TELEVISOR WHICH WAS USED IN NEW YORK DURING THE TRANSATLANTIC EXPERIMENTS.



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# CHAPTER XI

## SPEED LIMITATIONS OF TRANSMITTING MEDIUMS

ANOTHER important factor in connection with television, which has been only lightly touched upon so far, is the possible speed at which electrical impulses may be transmitted over a circuit, either wire or wireless.

In phototelegraphy two distinct methods of transmission have been developed, both of which are applicable to either wire or wireless circuits. In one of these methods the fluctuating output current of the light-sensitive cell, after suitable amplification, is caused to modulate a steady carrier current, in the case of wire communication; or a carrier wave in the case of wireless transmission. In both cases the effect of the modulation is similar to the modulation of the carrier which occurs in telephony.

The other method is somewhat comparable to telegraphy, inasmuch as the carrier current or wave is interrupted altogether, the picture



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impulses being transformed into entirely separate and discontinuous current or wireless impulses.

The former, or modulation method, gives by far the best results, for delicate degrees of impulse intensity can easily be transmitted by varying the degree, or depth, of the modulation. This tends to give more delicate differentiations of light and shade in the received picture.

When these delicate degrees of modulation have to be transmitted over great distances, however, the finer distinctions of current values tend to become smoothed out and lost. In the case of communication by wire or submarine cables over great distances, this smoothing-out effect is produced by the distributed inductance and capacity of the wire or cable circuit. This has long been one of the greatest difficulties which the cable companies have had to contend with in their efforts to speed up signalling, and, in the case of long submarine cables (where the effect is much greater), has entirely prohibited the establishment of long-distance transoceanic telephony.

Where the modulation method of picture transmission is done by means of wireless, the well-known fading effects which are experienced with long-distance wireless communication obliterate many of the finer shades of

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current impulses, and, thus, of the finished picture.

With the interruption method of signalling, although the results are necessarily much coarser of grain and devoid of fine distinctions of light and shade, the results obtainable over great distances are more reliable. It is this method which is used in the transmission of pictures between London and New York.

An important point in connection with both modulation and interruption systems of phototelegraphy, however, is that speed is not of such vital importance as it is in television. There is no reason why half an hour should not be occupied in the transmission of a single picture, in the case of phototelegraphy ; but in television a complete picture must be transmitted and received in not more than one-tenth of a second.

This rules out the interruption method of signalling entirely, for the speed of transmission is far too high for such a system to respond to. A simple calculation will reveal just how high the speed of signalling may be.

In order to get a received image of fair quality the least we can be satisfied with is 10,000 different values of light intensity. That is to say, the picture must be made up of at least 10,000 dots of light of different intensity, or the grain will be intolerably

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coarse, resulting in a very crude image. This may mean that the moving light spot will pass across the screen in ten parallel strips, each strip, or light-spot path, being subdivided into 100 different light values.

If this process is repeated over and over again at the cinematograph speed of sixteen pictures per second, it means that 160,000 changes of light value, or picture impulses, are required per second. Such a speed seems, on the face of it, inconceivable. Moreover, a good picture really requires an elemental basis of more than ten strips, so that a more suitable speed for the light impulses would be somewhere about 300,000 per second!

Thus, the light-sensitive cell at the transmitter, the light source at the receiver, and the medium of transmission between the two stations, must all be capable of responding to, and carrying, impulses occurring at a frequency of 300,000 per second.

The difficulties in connection with light-sensitive cells and light sources can, as has already been described in Chapter VII, be overcome by employing a plurality of cells and light sources.

Assuming that this is done, and that the outputs of all the cells are arranged to be sent over a single circuit, there remains the problem of transmitting 300,000 impulses per

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AN EXPERIMENTAL FORM OF THE BAIRD PHONOVISOR.

The image is viewed in the upright mirror mounted over the slot, beneath which is the revolving spiral disc and neon tube. See Chapter XII.



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second over that circuit. At such an enormous speed of operation, the interruption method is obviously ruled out, and it is questionable whether a wire circuit of the ordinary carrier current type could be arranged to transmit impulses at this frequency.

As far as submarine cables are concerned, transmission could not be effected over a single cable as they are designed to-day. The fastest existing cable, known as a permalloy cable, has a maximum operational capacity of about 500 words per minute for telegraphy. At this speed, only about 125 impulses per second are transmitted.

Wireless transmission does not offer a complete solution to the difficulty, for in order to overcome fading effects, it is necessary to use a very long wave-length, of the order of 10,000 metres or over, and at such high wave-lengths rapid transmission is not possible on account of the appreciable length of time it takes for an impulse, delivered to the transmitter, to charge up the long tuned antennas used in modern high-power long-wave wireless transmitters. If the speed of transmission is increased above a certain limit, depending upon the characteristics of the transmitting aerial, the latter will not have time to become fully charged; which means that individual impulses will be attenuated, or weakened, before they leave

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the transmitting aerial. Under such conditions, perfect reception is impossible, and the received image will suffer.

Going to the other extreme, i.e. using ultra-short wave-lengths, will overcome the difficulty of the speed of transmission, but as fading is more prevalent on short waves, the attenuation of impulses is only transferred from the transmitter to the receiver. However, by using methods already employed for high-speed radio-telegraphy purposes, the fading difficulty might be overcome. If not, there would appear to be no alternative but to employ several different channels, connecting each of several light-sensitive cells to a different channel; and at the receiver connecting a separate light to each channel. If this were done, then it could be arranged that the entire transmission be split up over the several channels, each taking a part of the picture, and thus lowering the speed of transmission over each individual channel.

There immediately arises, then, the difficulty of available channels, or wave-lengths, for there are so many wireless stations already in existence that there is but little room for further increase. However, if it were decided to use, say, seven channels, or wave-lengths, separated from each other by 100 kilocycles (thus giving a television wave-band 700 kilocycles wide), such a television wave-

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band might be placed between 20 and 21 metres.

In such a case, of course, seven separate wireless transmitters and seven separate receivers would be necessary, unless a Hammond multiplex system were employed. In the latter case, the seven carrier waves could all be radiated by a single aerial, and sorted out by a suitable receiving system, working off a single receiving aerial.

What the final solution of the problem will be still remains to be seen, after further research work has been carried out. As far as wire transmission is concerned, it is possible that a solution may be found by employing "wired wireless," i.e. by substituting a radio frequency carrier wave, or waves, for the ordinary D.C. carrier.

As far as Mr. Baird's experiments are concerned, the methods he uses have not, so far, brought the speed of signalling beyond the transmission capacity of ordinary telephone lines (this will be more fully explained in the next chapter), and he has on several occasions used them during public demonstrations of television over considerable distances, notably between London and Glasgow last May, a distance of about 430 miles. As far as wireless transmission is concerned, he is at present experimenting with short waves, and has already experienced difficulty, due to fading.

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In our last chapter, however, we shall describe how these experiments culminated in the spanning of the Atlantic.

Where wireless transmission of television is employed, the received image is liable to electrical distortion if all the apparatus used is not properly adjusted, and its effects are almost as distressing as distortion in a loud speaker. The difference, of course, is that it is not music, but the image which suffers.

Fortunately, distortion in television is easily remedied, much more so than in the case of a loud speaker, for each effect can be *seen*, and the eye is a more reliable measuring instrument than the ear.

Interference, such as is experienced by broadcast listeners, affects television also when it is transmitted by wireless. With television, interference takes many peculiar shapes. The whoops and whistles which frequently mar radio reception appear on the televisor screen as small snowstorms—a mass of whirling white flakes passing across the screen—while interference caused by electric light mains appears as a series of white bands moving up and down the image. Atmospherics appear in the form of white flashes.

It would be very convenient indeed if we could combine broadcasting with television, using the same wave-length, so that, by means of a single receiver, we could tune in to our

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ILLUSTRATING THE APPEARANCE OF A PHONOVISION TEST RECORD.

When "played" over, using an electrical pick-up, the indentations are converted into electrical impulses which, when fed to a televisor, reproduce the recorded image visibly and recognisably on the screen.



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favourite station, and both see and hear what was taking place in the studio; but this alluring suggestion must, it is to be feared, be put aside, for the time being at least.

As we have already seen, the demands made upon the transmission medium are so great that the problem of sending the television impulses alone over a single channel is sufficiently imposing, without complicating it by the addition of speech and music frequencies.

The A. T. & T. Co., in their demonstration, used three channels in all, one for television impulses, one for the synchronising frequency, and one for speech. Mr. Baird, by sending the television and synchronising currents over the same channel, has been able to give his demonstrations with the use of but two channels, and, for the time being at least, it would appear that this is the best that may be hoped for. Subsequent research, of course, may indicate a way out of the difficulty, but at the present time the position remains as described above.

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# CHAPTER XII

## PHONOVISION AND NOCTOVISION

ALTHOUGH the speed of signalling, as we have seen in the last chapter, may, theoretically, run into hundreds of thousands of impulses per second, it does not necessarily follow that the full total number of impulses does actually flow through the circuit during any given second. Far from it.

What is meant is that, if a single image is divided up into 10,000 picture elements, and ten pictures are sent in one second, the circuit should be *capable* of transmitting 100,000 impulses per second, if required. With the average picture this heavy demand will not be made, for there are usually comparatively large areas of a picture or scene which have the same tone depth. That is to say, large areas of the scene will reflect the same amount of light to the television transmitter.

The result of this is that certain image strips may have practically the same density throughout. For example, consider an image strip in which one half is completely dark,



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while the other half is brilliantly illuminated. That particular strip, in passing over the light-sensitive cell, for fifty of its 100 subdivisions, will register nothing on the cell; for the remaining fifty, maximum illumination will fall on the cell fifty times running, which corresponds to a single extended current impulse, instead of fifty short impulses of varying intensity.

Thus, instead of giving rise to 100 separate current impulses, that particular image strip causes but one impulse, which is repeated at the same intensity, which is equivalent to a single long impulse.

This example, although perhaps rather extreme, serves to illustrate the principle that although the mechanism employed may be *capable* of dividing the image up into 10,000 consecutive light flashes, so many of these light flashes, occurring consecutively, may have exactly the same value, that it is seldom that 10,000 different current impulses are required accurately to reconstruct the picture.

In practice, the current impulses appear to follow one another in groups or trains, like the damped wave trains set up by the discharge of a Leyden jar. If a pair of head phones is plugged into the circuit at a suitable point, these trains of impulses can be heard as an irregular series of sounds, the regularity and character of them depending

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upon the subject placed in front of the transmitting televisor, and upon the amount of movement in the subject.

With a little practice, in fact, it is possible to tell by the sounds heard what it is that is being televised. Every human face gives out its own characteristic image sound, and after listening for some time it becomes possible to recognise the sitter by the sound of his or her face!

It is these sounds which are used to modulate the carrier wave if wireless transmission is being employed, and if the transmission is listened to on an ordinary radio receiver these sounds can be heard quite distinctly.

For example, the face of an individual looking straight at the transmitter sends out a series of sounds something like "Brump, brump, brump," etc.; but when turned sideways the profile produces a note like "Perahh, perahh, perahh," etc. A hand with fingers extended, if passed in front of the transmitter, sounds like the grating of a very coarse file, or a saw; and an inanimate object, such as a box, gives a single steady note. This the animate object cannot do, for the slightest movement of the features is turned into sound waves by the action of the transmitter.

This ability to hear the image impulses opens up important possibilities, for if the impulses can be heard, they can also be

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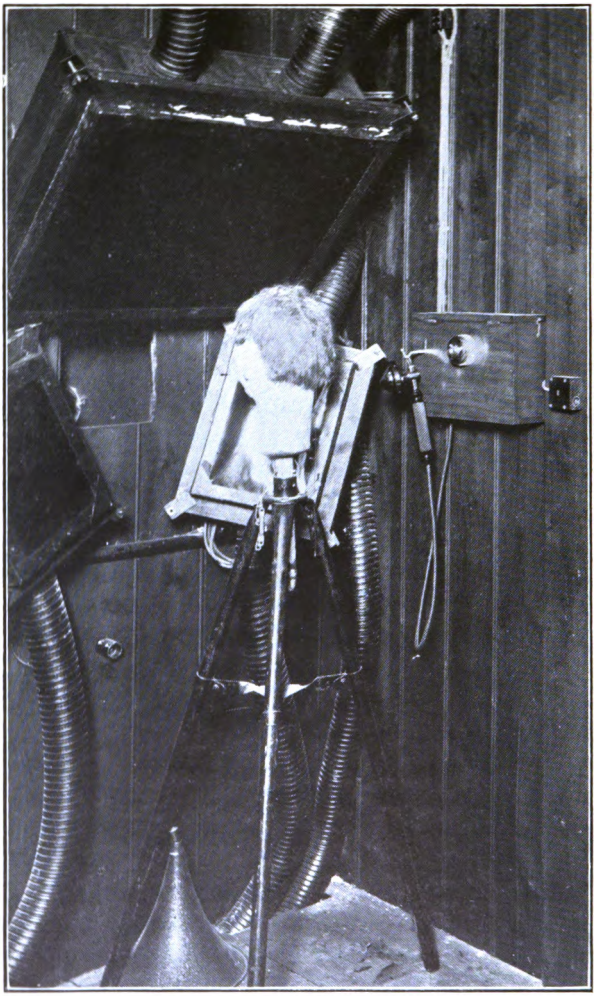

THE BAIRD NOCTOVISOR.

The banks of lamps on both sides and above are covered with ebonite filters, which allow only infra-red rays to pass. The pipes are for ventilation only.



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recorded on a gramophone record. Mr. Baird has interested himself considerably in this possibility, and has initiated many experiments in the recording of image sounds.

Once recorded, these image sounds can be played over on an ordinary gramophone and thus made audible again. There is not much value in such an accomplishment in itself, except for the novelty of listening to a face, or for demonstration work at lectures, etc.

The real potential value of the development lies in the fact that the indentations of the records can be transformed back into visible images again! To do this, the ordinary gramophone sound-box is replaced by an electromagnetic pick-up device, which turns the indentations on the record into electrical impulses, which, after amplification, are caused to vary the light source of a television receiver. It is not necessary to synchronise, as the exploring disc and vision record are driven from the same motor.

This combination of gramophone and televisor, which is still in the laboratory stage of its existence, Baird calls a "Phonovisor." As will readily be appreciated, it offers immense possibilities as an alternative to the cinematograph film as a means of recording scenes permanently, so that they may be reproduced at will at a later date.

Another of Baird's developments, of which



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much has been written in the Press, is "noctovision," which will now be described.

During the first demonstrations of true television, tremendously powerful lights were necessary in order adequately to illuminate the sitter whose image was to be transmitted to distant points. So powerful were these lights, in fact, that the unfortunate "victim" was well-nigh blinded and burned by their intensity, and Baird was once told that even a music-hall star would shrink from such an intense spot-light!

Improvements in the light-sensitive cell have now enabled him to dispense with such intense illumination, the lighting now used being, in fact, comparable with that in use at a photographic studio. In fact, ordinary daylight can now be employed, as described later on in this book.

It was whilst he was working on the problem of reducing the amount of light required that the thought occurred to Baird: Why not dispense with visible light altogether and use invisible rays?

In order fully to understand this latest suggestion, and the developments which arose out of it, it might as well, at this point, to consider briefly the spectrum.

Readers who are enthusiastic broadcast listeners will know that wireless waves are electrical vibrations the frequency of which

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depends upon the wave-lengths. The longer the wave-length the lower the frequency. Wireless waves extend in length from a few centimetres, used only in the laboratory, to about 30,000 metres, as used by the great high-power transoceanic wireless-telegraph stations. The frequency of vibration of a 1-metre wave is 300 million cycles per second, and that of a 30,000-metre wave is 10,000 per second.

Wireless waves, however, occupy but a small part of the spectrum. Visible light and the various invisible rays are, to-day, accepted as vibrations in the ether, just like wireless waves; only the frequencies at which light and other rays vibrate are very much higher than those of even the shortest wireless waves. A diagrammatic representation of the spectrum, showing all the known frequency bands and the uses to which they are put, is given in Fig. 31.

Of all the component parts, or sections of the spectrum, that section which is most familiar to non-technical members of the public is the visible spectrum. This contains the colours, and extends from violet, at the high-frequency end of the spectrum, to red at the lower end. As the frequency of the vibrations is reduced, so we pass through the entire range of colours, violet, indigo, blue, green, yellow, orange, and red.

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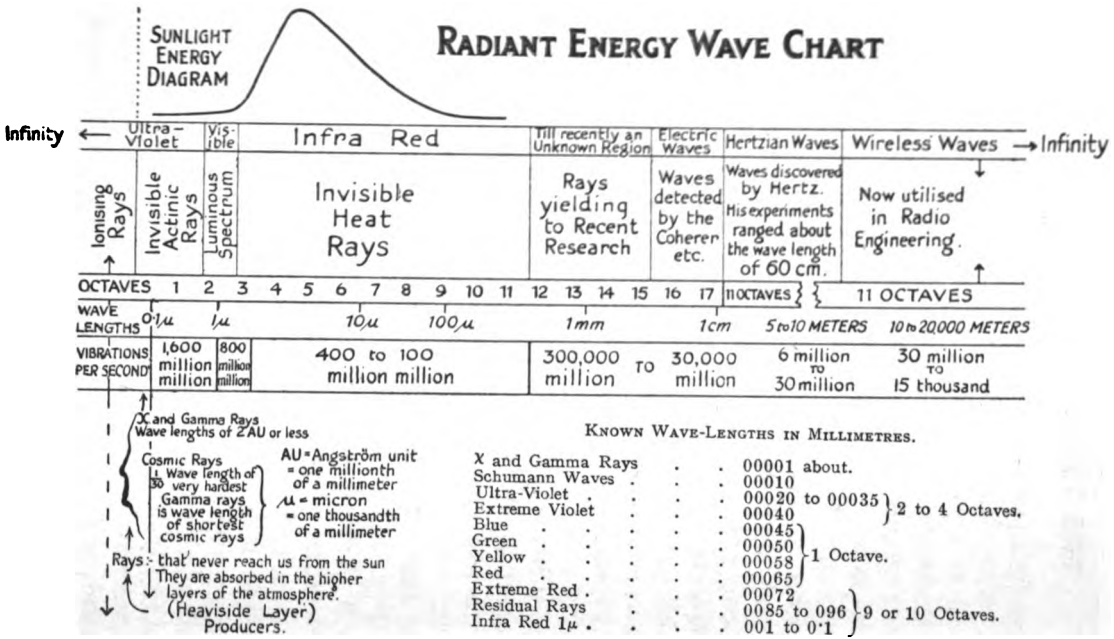
SUNLIGHT ENERGY DIAGRAM
RADIANT ENERGY WAVE CHART
Infinity
Ultra-Violet
Visible
Infra Red
Till recently an Unknown Region
Electric Waves
Hertzian Waves
Wireless Waves
Infinity
Ionising Rays
Invisible Actinic Rays
Luminous Spectrum
Invisible Heat Rays
Rays yielding to Recent Research
Waves detected by the Coherer etc.
Waves discovered by Hertz. His experiments ranged about the wave length of 60 cm.
Now utilised in Radio Engineering.
OCTAVES 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
11 OCTAVES
11 OCTAVES
WAVE LENGTHS
0·1μ
1μ
10μ
100μ
1mm
1cm
5 to 10 METERS
10 to 20000 METERS
VIBRATIONS PER SECOND
1,600 million million
800 million million
400 to 100 million million
300,000 million
TO
30,000 million
6 million TO 30 million
30 million TO 15 thousand
X and Gamma Rays
Wave lengths of 2 AU or less
Cosmic Rays
1 Wave length of 30 very hardest Gamma rays is wave length of shortest cosmic rays
AU = Angström unit = one millionth of a millimeter
μ = micron = one thousandth of a millimeter
Rays that never reach us from the sun
They are absorbed in the higher layers of the atmosphere.
(Heaviside Layer)
Producers.
KNOWN WAVE-LENGTHS IN MILLIMETRES.
X and Gamma Rays . . . 00001 about.
Schumann Waves . . . 00010
Ultra-Violet . . . 00020 to 00035 } 2 to 4 Octaves.
Extreme Violet . . . 00040
Blue . . . 00045
Green . . . 00050
Yellow . . . 00058 } 1 Octave.
Red . . . 00065
Extreme Red . . . 00072
Residual Rays . . . 0085 to 096 } 9 or 10 Octaves.
Infra Red 1μ . . . 001 to 0·1

FIG. 31.—THE FREQUENCY SPECTRUM.

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Of the entire frequency spectrum, the unaided human senses are only capable of responding to, or detecting, the colours lying between violet and red, i.e. the visible spectrum. To detect the other frequencies, special instruments are necessary, such as, for example, a wireless receiver, when it is desired to detect wireless waves, or a fluorescent screen when it is desired to make visible X-rays or cathode rays.

As was explained in Chapter IV, photo-electric cells are most sensitive to light rays lying at the upper end of the spectrum; such as, for example, ultra-violet rays. These latter are invisible to the unaided human eye.

Selenium cells, on the other hand, are most sensitive to light rays lying at the lower end of the spectrum; such as, for example, infra-red rays, which are also invisible.

In his first attempts to apply invisible rays to his televisor, Baird turned to the upper end of the spectrum and tried ultra-violet rays. He found, however, that although the use of these rays gave results, they also caused serious discomfort to the eyes of sitters. Furthermore, ultra-violet rays have an extremely low penetrative power. They will not penetrate glass to any extent, and they soon become absorbed by the atmosphere.

Dissatisfied with these rays, Baird turned to the other end of the spectrum, and used

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infra-red rays. These rays, although they do not give such a strong photoelectric effect as ultra-violet rays, have a far greater penetrative power, and are not absorbed to any appreciable extent. Furthermore, they have no injurious effects upon sitters.

By using these rays in place of visible light, it was soon possible to dispense with visible light altogether, with the somewhat startling result that it has now become possible to see in total darkness!

This, perhaps, is the most spectacular development of all in connection with television, and it has a most uncanny and impressive effect upon visitors to a demonstration. The sitter goes into the transmitting studio, and is immediately enveloped in complete darkness. He can see nothing, and yet his every movement is plainly visible on the televisor receiving screen. There is little difference in the appearance of the received image whether visible light or infra-red rays are employed to illuminate the sitter.

There are many purposes for which noctovision, as seeing in darkness has been called, might be usefully employed. Its value in warfare, for example, might well be incalculable, for, by "illuminating" the enemy's position at night by means of an infra-red ray search-light, the rays of which would be invisible to him, and by using in con-

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junction with it a televisor, surprise night attacks would be rendered impossible, for the movements of the attackers would at all times be under observation.

It is to be hoped, however, that other uses may be found in times of peace for this latest development of television. The fact that infra-red rays (in contrast to ultra-violet rays, which are speedily absorbed by ordinary atmosphere) possess very great powers of penetration opens up possibilities in connection with the navigation of ships and aircraft during foggy weather.

In order fully to understand the possibilities in this direction it is only necessary to consider the behaviour of ordinary visible light during foggy weather. The most intense white lights, it will be noticed, show through fog as a dull red colour. The thicker the fog the duller the red which shines through.

This phenomenon is not due to any change in the characteristics of the original source of the light. The fact is that any given light source emits, not one single colour of light, but several, which combine to give the effect of a single colour when looked at with the naked eye. This can easily be demonstrated if a beam of sunlight is allowed to shine through a prism on to a wall. Not only will the light beam be bent away from its original direction, but the reflection seen on

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the wall will not be a monochrome spot of light, but a brilliant collection of all the colours of the rainbow.

By means of suitable filters, all the colour components of a beam of light, except one, can be eliminated; and fog acts as a filter which will only pass red light.

An everyday example of the phenomenon can be seen at sunset on a cloudless but slightly hazy day. As the sun sinks into the haze near the horizon it turns redder and redder, until, just before it finally disappears, it looks like a ball of fire. Actually, the light shining from the sun has not changed at all; it is the haze which filters out, or absorbs, all other colours, allowing only the red component to reach the observer.

The fog-penetrating power of light varies as the fourth power of the wave-length, so that red light penetrates fog some sixteen times better than blue light, and infra-red rays some sixteen to twenty times better still.

Red light has already come widely into use in aerodromes and other places where powerful fog-penetrating lights are required. This new application of television renders possible the use of infra-red rays with their still greater penetrative powers.

They will not, of course, be visible to the naked eye, even through fog. It will be

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THIS IS NOT A SNOW SCENE, BUT A VIEW PHOTOGRAPHED BY INFRA-RED RAYS BY PROF. R. W. WOOD (U.S.A.).

Filters placed in front of the camera lens cut off all visible light and admit to the sensitive plate only the infra-red rays reflected back from the scene.



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necessary at the receiving end (e.g. on board a ship at sea) to make use of a televisor in order actually to *see* through fog.

In order to generate infra-red rays any form of lamp may be used which will provide the necessary intensity of illumination, although certain types of lamps are richer in infra-red rays than others. Having selected a suitable light source, to obtain infra-red rays from it, all that is required is a filter which will cut off all the light frequencies but those belonging to the infra-red rays. Several substances may be used as filters, such as, for example, hard rubber, or ebonite.

Thus, in order to transform an ordinary searchlight (the arc of which is already very rich in infra-red rays) it is only necessary to cover the front of it with a sheet of a suitable filter substance.

For ordinary noctovision at short range (i.e. in the studio) it is only necessary to cover the studio lights with an infra-red filter. If banks of lamps are used to illuminate the sitter, they can be boxed in, and the front covered with an ebonite sheet.

For ordinary television purposes there is, of course, no particular advantage to be gained from the use of infra-red rays, for it means that the object or scene being televised is, so far as the human eye can see, in total darkness; and Mr. Baird does not employ invisible rays

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for his television transmissions, but uses ordinary flood lighting such as is used in a photographer's studio.

Thus, it is likely that noctovision will be developed independently of television (using visible light), and be specially developed for such particular purposes as have been suggested above.

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# CHAPTER XIII

## SEEING ACROSS THE ATLANTIC

ON February 9th, 1928, the world was startled to learn that during the early hours of the morning of that day, persons seated in London were clearly seen and recognised in New York! This means that the Atlantic has been spanned by television, a distance of over 3,500 miles.

For months prior to the demonstration, secret experiments had been going on, using short-wave wireless as the transmitting medium.

On the night of the demonstration there assembled at Baird's laboratory in London a small party made up of Press representatives and privileged guests, the author having the honour to be numbered among the latter. The transmissions commenced at midnight on the 8th, London time; or 7 p.m. on the 8th, New York time.

In order to give the watchers at the New York end an opportunity to adjust the receiving apparatus, the image of a ventriloquist's



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doll was first transmitted, a doll being used because of the need for steadiness of the image during adjustment.

The image sound of this doll, which sounded for all the world like the drone of a huge bee, was then sent over a telephone line to Baird's private experimental wireless station at Coulsdon, Surrey. The station has a power of only 2KW, and operates under the call sign 2KZ. From this station the image sound was then flashed across the Atlantic on a wave-length of 45 metres.

On the American side, the signal was picked up by an amateur receiving station at Hartsdale, a small town a few miles out of New York City. After amplification the signal was then applied to the receiving televisor, upon the ground-glass screen of which the image appeared. This screen measured about two inches by three inches.

Four watchers were anxiously gathered round the apparatus. These included Reuter's Press representative, Mr. Hart, the American owner of the receiving station, and two of Mr. Baird's representatives, who had gone to New York specially to supervise the tests.

When the image of the doll's head had been satisfactorily tuned in, Mr. Hart started up his wireless transmitter, the call sign of which is 2CVJ, and called Baird's receiving station

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at Purley. Using the Morse code, Mr. Hart asked that Mr. Baird should take his place before the transmitter instead of the doll. This message was telephoned from Purley to the transmitting laboratory in London.

For half an hour Mr. Baird sat before the transmitter, moving his head this way and that, until the message came through from New York that his image had come through. One of the Press representatives then took Mr. Baird's place, and continued to sit before the transmitter until word came through that his image was coming through very well. It appeared that this particular sitter's features were unusually striking, from a television point of view, and transmitted better than those of other sitters.

The wife of an American journalist who was present then took her place before the transmitter, and, although her features were not recognisable at the American end owing to atmospherics and fading of signals, there was no mistaking the fact that a woman was seated before the apparatus in London.

Those assembled at the London end were able to see, on a check receiver, a pilot image of what was being transmitted. This image, which was full size, showed the head of the sitter, the complete details of the features showing in black relief on an orange-coloured background. By means of this pilot image

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the transmitting operator was enabled to check the outgoing transmission and correct any irregularities. From his control position in front of this pilot image, also, the operator was able, by means of a microphone and loud speaker, to give instructions to the sitter as to what movements he should make to keep in focus, turn profile, etc.

Atmospherics and other interference, and also fading of signals, marred the image as received at the New York end at times, but in spite of these disabilities reception was, on the whole, very good. The demonstration proved quite conclusively that if a much higher-powered wireless transmitter had been employed, the image would have been received in New York entirely free from atmospheric and other disturbances. The experiment also confirmed the statement which Baird has always made, to the effect that distance is merely a matter of power, and that it has no connection whatever with any development of the television apparatus itself.

Again in contrast to the A. T. & T. demonstration, Baird's transatlantic demonstration required the services of but two operators to attend to the television transmission, one at each end of the circuit.

On the night of March 5th–6th, 1928, these experiments were repeated on board the Cunarder *Berengaria* in mid-Atlantic, while

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the receiving equipment was being brought back home from New York. The wave-length used was the same as before, 45 metres, and the demonstration was carried out without any interference at all from the liner's normal wireless installation, which was at work on longer wave-lengths.

A little group of people, including passengers, and some of the ship's officers, crowded together in a small reception room and saw projected on the televisor screen images of people sitting in the laboratory of the Baird Company in London. What they saw is perhaps best described in the words of Mr. W. Sutcliffe, Staff Chief Engineer of the *Berengaria*, who states in a letter published in the May issue of the *Television Magazine*:

"On looking at the screen of the televisor, I saw rapidly moving dots and lines of orange light which gradually formed themselves into a definitely recognisable face. This image varied from time to time in clarity, but movements could be clearly seen, and the image, when clear, was unmistakable."

Another witness of the experiments was Mr. Stanley W. Brown, Chief Wireless Operator of the liner, who recognised on the screen the image of his fiancée, Miss Dora Selvey, who had been specially invited by the Baird Company to sit before the trans-

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mitter in London. Mr. Brown recognised Miss Selvey first by her characteristic style of hairdressing, and was later convinced of her identity beyond all question when she turned profile.

This remarkable achievement clearly demonstrates a noteworthy field of utility for television. Years ago, passengers setting out on a long sea voyage lost all touch with their friends on land until they arrived at their destination. Now, thanks to wireless telegraphy, voyagers and their friends may keep in close touch telegraphically. With the convincing evidence of the *Berengaria* demonstration fresh in our minds, it is surely not too great a flight of imagination to visualise the time, not far distant, when those who go down to the sea in ships may be able to keep also in visual touch with those whom they have left behind them.

There are signs already that this vision of the future may soon become a reality, for it has been announced by a group of American financiers who have taken over the American rights of certain of Mr. Baird's inventions, that they intend to make the *Leviathan* (America's largest liner) the world's first mobile television station. Negotiations are already in progress, it is understood, to equip the *Leviathan* with a television transmitter and receiver, working on the Baird system.

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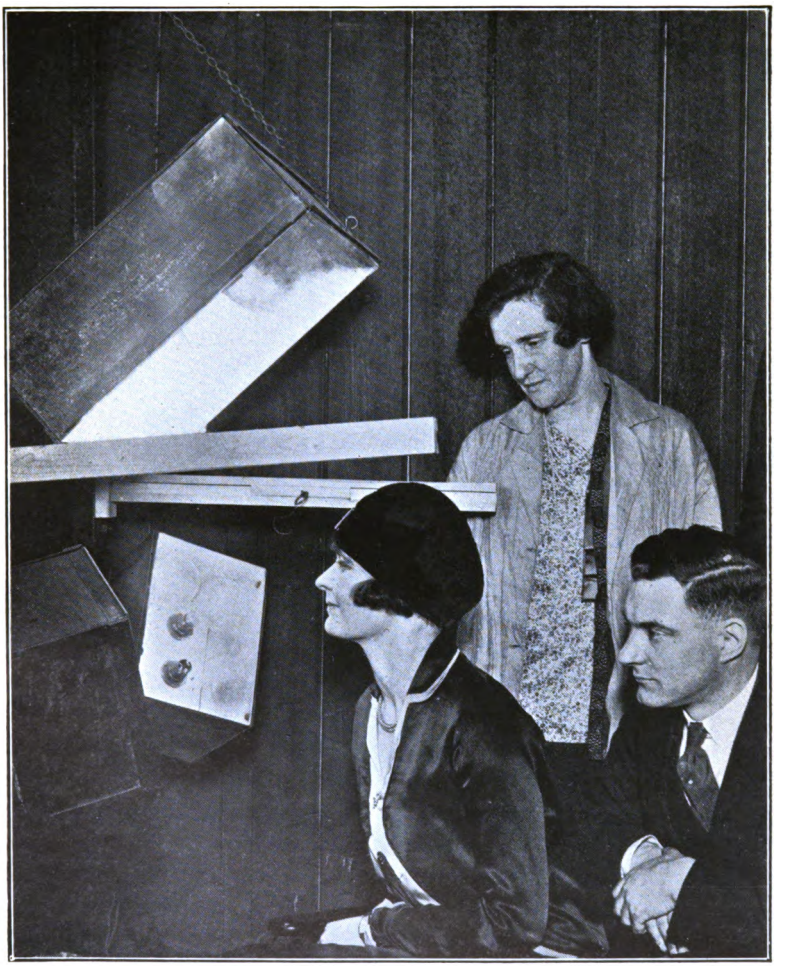

MRS. HOWE (left)—THE FIRST WOMAN WHOSE IMAGE WAS TELEVISED ACROSS THE ATLANTIC—SEATED BEFORE THE TRANSMITTER.



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# CHAPTER XIV

## TELEVISION IN DAYLIGHT AND TELEVISION IN COLOURS

ONE of the latest advances in television, made by Baird in June 1928, is the accomplishment of television by daylight. In previous chapters we have seen how the intense artificial illumination formerly required was gradually reduced to ordinary photographic studio brilliancy, by increasing the sensitivity of the light-sensitive device. By using the light-spot system it became necessary only to illuminate the face of the sitter by means of a tiny travelling spot of light. Then, by utilising infra-red rays, Baird was able to televise a person seated in what was apparently total darkness.

As a result of further improvements in his light-sensitive device, Mr. Baird has now been able to remove his television transmitter from his laboratory and place it on the roof, so that the subject to be televised sits in ordinary daylight. Brilliant sunshine is not necessary; the apparatus functions perfectly



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even on a dull day, giving, on the receiving screen, an image equally as good as that obtainable when artificial light is employed to illuminate the subject.

The importance of this advance lies in the fact that, for the first time, it has been possible to remove the television transmitter from the laboratory. A more extended field of view can be dealt with by daylight, and this marks the first step towards the day when it will be possible for us to witness at a distance, by television, such great outdoor events of national importance as the Derby or the Boat Race. Much still remains to be done before this will be possible, but the important point is that the first step has been taken.

The possibility of transmitting television in colours has been visualised for some considerable time by those intimately connected with television developments, but this advance was only achieved practically on July 3rd, 1928, when, by employing a three-colour process, Mr. Baird was able to demonstrate the transmission of images in their natural colours.

This process is extremely interesting, and is essentially very similar to the process employed in one of the forms of colour cinematography. It consists in presenting to the eye, in rapid succession, first a green image, then a blue, and then a red image.

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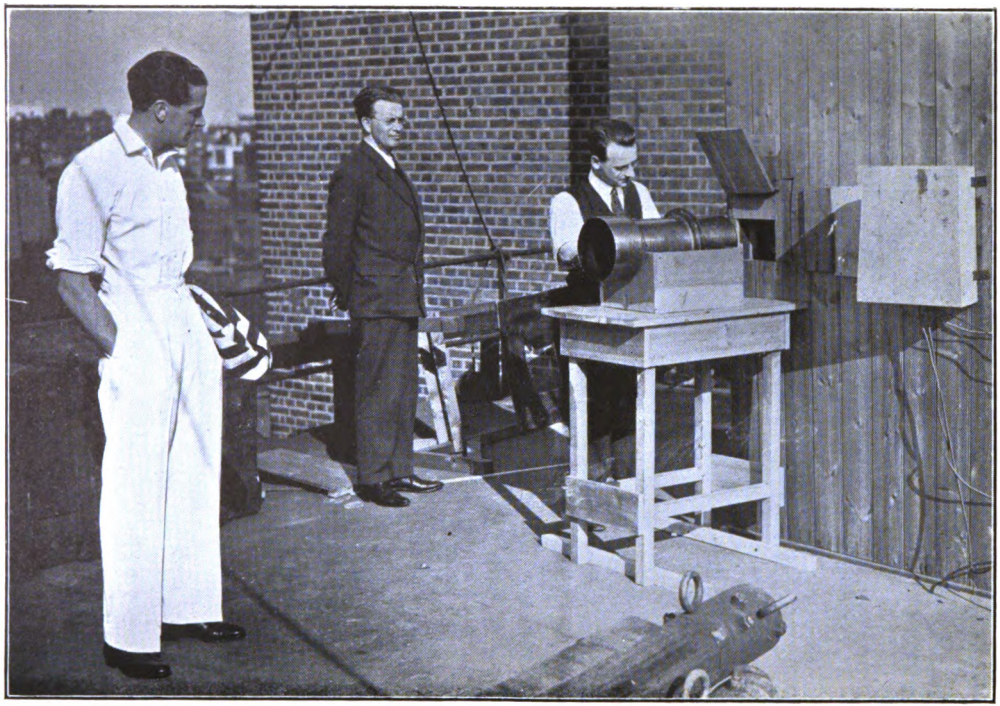

ANOTHER FORM OF THE DAYLIGHT TELEVISION TRANSMITTER WHICH, BY MEANS OF THE LARGE LENS, IS CAPABLE OF EMBRACING A LARGER FIELD OF VIEW.

A full-length image is being transmitted of Mr. Jack Buchanan (in flannels), the actor, who is an old school chum of Mr. Baird, who is seen standing with his hands behind his back.



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These three colours form the well-known primary colours, from combinations of which any other colour or tint may be obtained. For example, purple is a mixture of red and blue, yellow is a mixture of green and red, and all other colours excepting the three primaries, red, green, and blue, are in a similar way composites of these three colours in varying proportions. When the three colours are combined together they give to the human eye an impression of white.

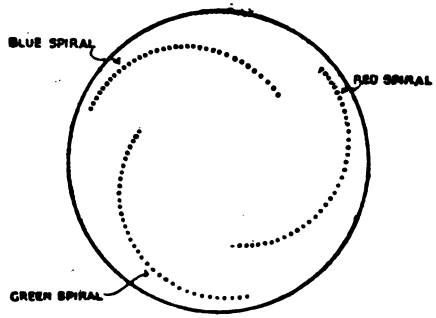


FIG. 32.—THE SPIRAL DISC USED FOR COLOUR TELEVISION.

The actual mechanism used in these first experiments consisted of a disc perforated with three spirals of holes (thirty-six holes in each spiral) arranged consecutively round the disc, as shown in Fig. 32. This disc was used in conjunction with the light-spot system which has already been described in previous chapters. By using a disc with three sets of perforations it was possible to traverse the subject to be transmitted firstly with a blue spot of light, secondly with a red spot, and



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thirdly, with a green spot, the perforations being covered with blue, red, and green light filters, as shown in Figs. 32 and 33.

The operation of this mechanism, therefore, caused the light-sensitive cells to transmit first a picture which showed only the blue parts of the scene, then a picture showing only the red parts, and lastly a picture showing only the green parts of the image.

At the receiving station a similar disc was used, the three sets of perforations, or spiral apertures, being covered by blue, red, and green filters respectively in a fashion similar to those of the transmitter disc. The difficulty at the receiving station, however, was to find a light source capable of generating blue, red, and green rays.

The neon tube which has hitherto been used for reception, while exceedingly rich in red rays, has practically no blue and green components. In order to solve the problem, an attempt was made to construct a special glow-discharge lamp by mixing neon, helium, and mercury vapour. This experiment proved unsatisfactory, because the blue and red components, and also the green component, varied their proportions, depending upon variable conditions in the lamp.

A solution of the difficulty was ultimately arrived at by making use of two separate lamps, one a glow-discharge lamp containing

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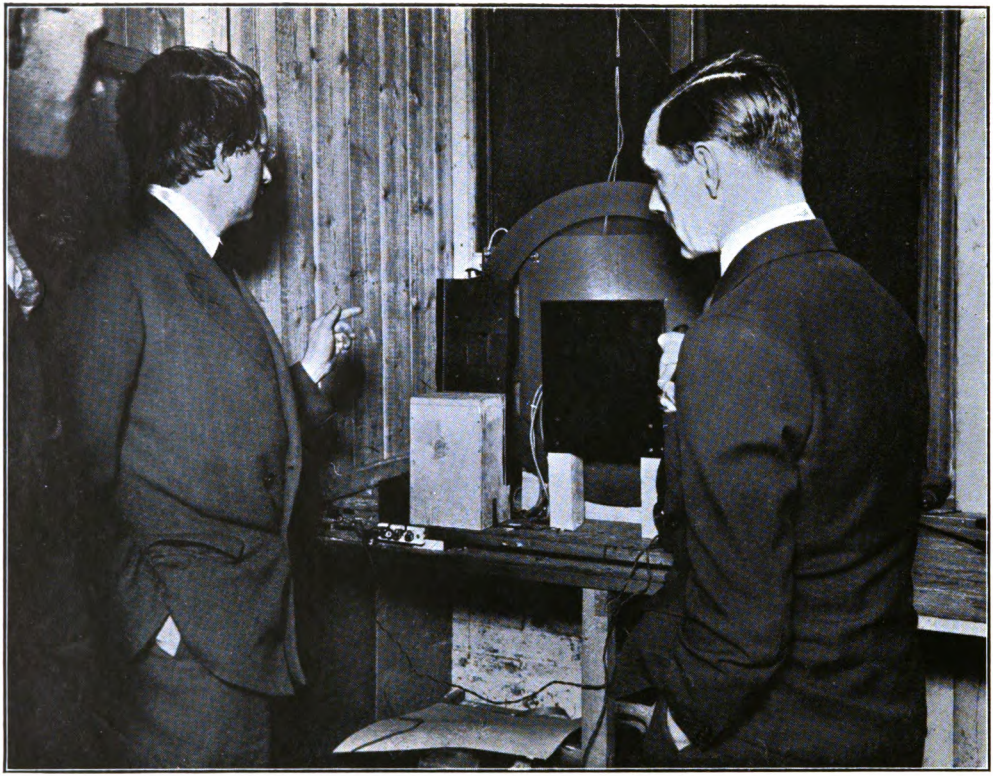

THE COLOUR TELEVISION RECEIVER IN ITS LABORATORY FORM.

Behind the slotted shield (on the left) is the revolving disc, behind which, in turn, are the neon and helium and mercury tubes.



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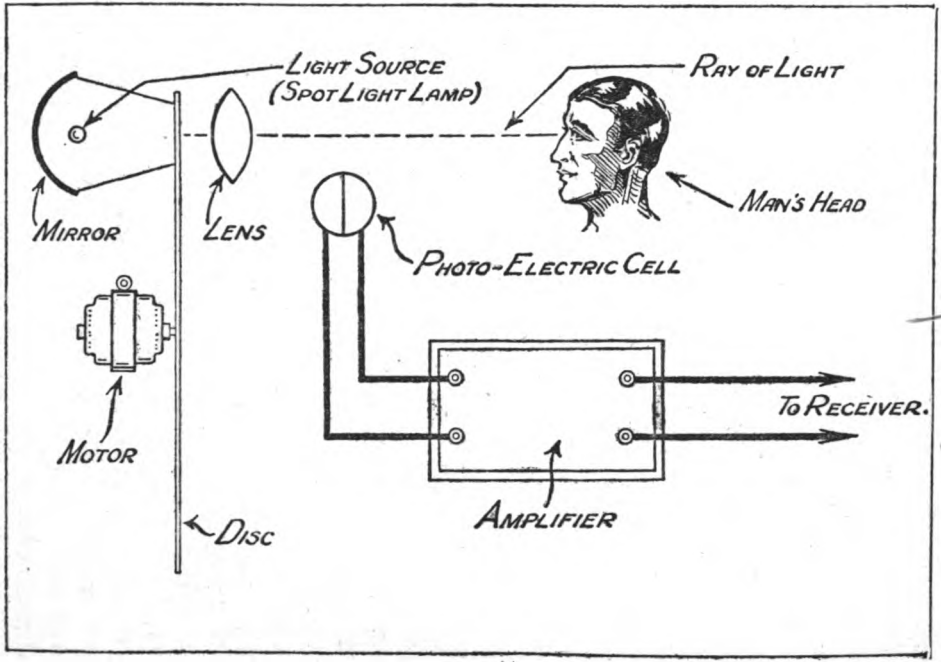


Fig. 33.—Diagrammatic Representation of Complete Colour Television Transmitter.

The disc has three spirals of red-, blue-, and green-covered holes, through which a light spot shines on to the object to be transmitted. Coloured light reflected back from the object affects a photo-electric cell or battery of cells placed as shown.

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neon and the other containing helium and mercury vapour, the mercury vapour providing a very intense green component and also part of the blue. The addition of helium in this lamp assisted in the production of the blue component.

By means of a commutator it was arranged that while the red viewing holes of the receiving disc were between the eyes of the viewer and the lamps, only the neon lamp was illuminated, and when the blue and green holes had rotated to the correct position the helium and mercury lamp was switched into circuit. The layout of the receiver is shown in Fig. 34.

It will be seen that in this arrangement, although there are three separate images, these images are transmitted in succession, and only one channel of communication is necessary for transmission.

On the other hand, the rate of transmission must theoretically be increased three times, as there are three times as many images being transmitted per second. In practice, however, it is found that it is not necessary to increase the speed so greatly, for the images have many parts in common, and a much lower speed may be used without introducing a disagreeably noticeable flicker.

By means of this apparatus very successful demonstrations of colour television were

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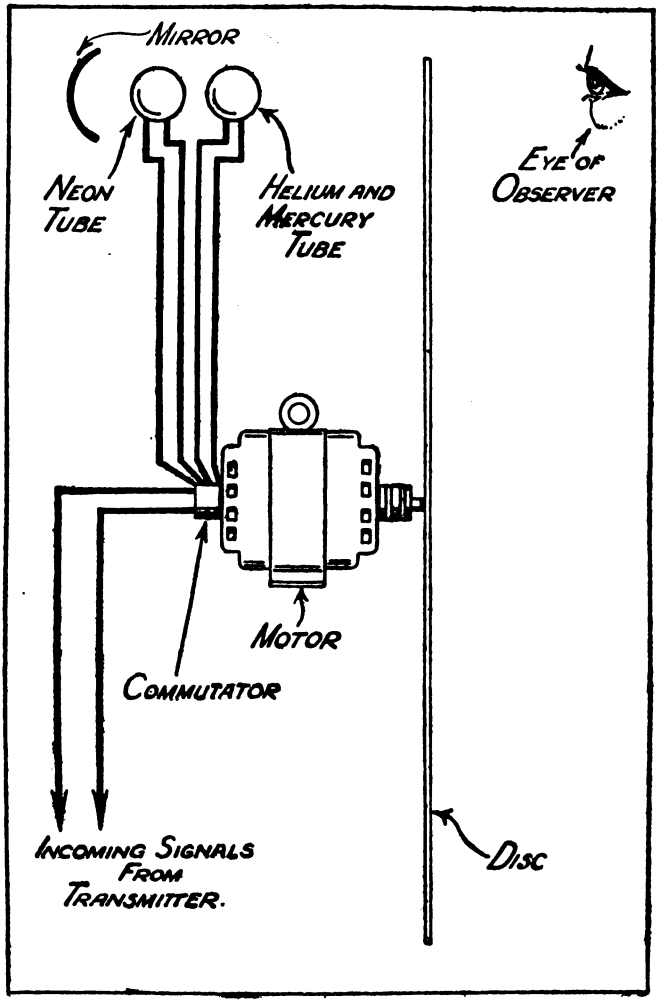


FIG. 34.—DIAGRAMMATIC REPRESENTATION OF THE COLOUR TELEVISION RECEIVER.

When the red spiral of holes in the transmitting disc is passing through the exploring light spot, it is arranged that the eye of the observer at the receiver shall also be looking through the receiver red spiral at the neon tube. When the blue and green spirals are passing through the light spot, the observer looks through the blue and green receiver spirals at the helium and mercury tube combination. Colours are reproduced by the combined effect of the different coloured spirals.



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given, and such objects as flowers, baskets of fruit, and other coloured articles such as a policeman's helmet appeared very vividly in their natural colours. Various shades of colour were also transmitted, a human face being portrayed on the receiving screen in a shade of pink different from that of the tongue.

The addition to television of reproduction in natural colours indicates a greatly increased field of utility, as obviously there are many objects and scenes which depend for their visual value entirely upon colour; one has only to witness colour cinematography as compared with the ordinary black-and-white film to appreciate in full the force of these remarks.

The author had the privilege of being present at demonstrations both of colour and of daylight television. The colour transmission demonstrations were amazingly vivid, the colours standing out most strikingly, particularly in the cases where the images of flowers and fruit were being received. The natural effect of the images, as seen on the televisor screen, was very greatly improved by the addition of colour, and colour television unquestionably marks a very great advance and opens up an entirely new field in television research.

In colour television, due to the absorption

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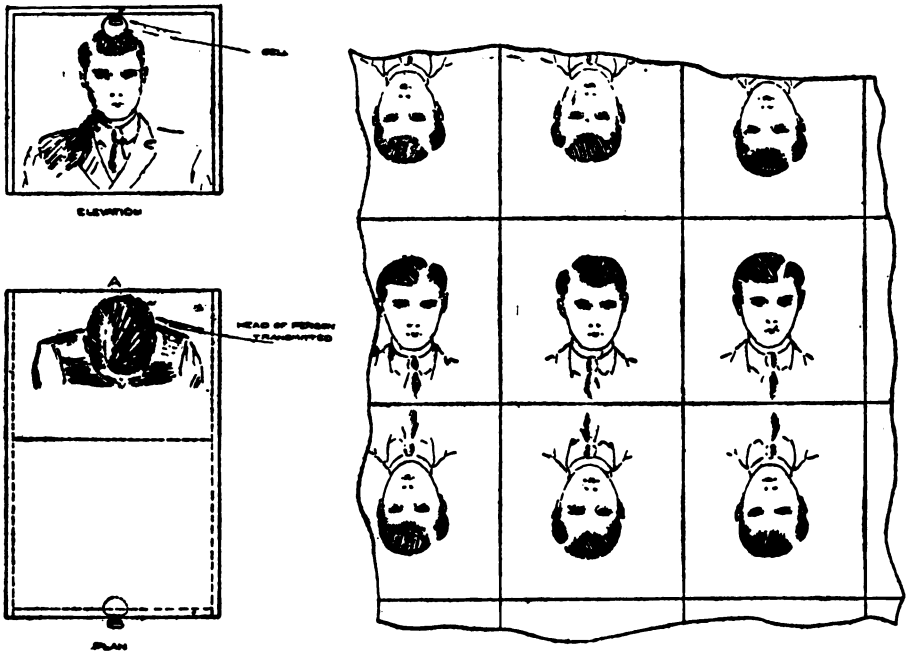

FIG. 35.—SHOWING HOW THE MIRRORS ARE ARRANGED ROUND THE OBJECT TO BE TRANSMITTED.

An eye at the point B would see a series of multiple images. The use of these mirrors greatly increases the total amount of light reflected back from the object. The effect is as if a great number of light spots were in action simultaneously, due to the multiple reflection in the mirrors.

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of the colour filters, only a very small amount of light is thrown back upon the photo-electric cells, and to increase this amount, an arrangement of mirrors is used in the form of a box around the object and cells, so that the effect of multiple images is obtained and the effective light is multiplied very greatly. The arrangement is shown in Fig. 35.

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# CHAPTER XV

## STEREOSCOPIC TELEVISION

ON August 9th, 1928, still another remarkable advance was demonstrated in the Baird Laboratories—television in stereoscopic relief. Before proceeding to describe this development it is, perhaps, desirable to describe briefly a phenomenon of vision which is seldom appreciated, especially by the younger generation who do not remember the stereoscope which was at one time to be found in almost every household as a form of parlour entertainment.

To those of us who still retain the unimpaired use of both eyes, all vision is stereoscopic. That is to say, when we look at any object or scene we gain an impression of stereoscopic relief, depth, or distance. From it we derive a sense of proportion. A distant house, as seen through the window, may appear no bigger than the flower pot standing on the window table, yet our eyes tell us that the apparent similarity in size is due entirely to the fact that the house is much farther away and is, as an artist would say, foreshortened.



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The false impression is, of course, corrected very largely by our experience, which tells us that a house and a flower pot are two totally different things. We know from experience that a house is a vastly larger object than a flower pot. But show the same scene to a savage who has never seen either a flower pot or a house, and he will be able to tell you that the house is a much bigger thing than a flower pot.

The savage is able to do this because the use of his two eyes gives him an impression of distance. He can estimate how far away the house is, and by comparison draw the conclusion that the house is a much larger object, even though he has never seen one before. Had he but one eye, however, the picture which he saw would be flat, like a scene on a cinema screen, and, having no previous experience to guide him, he would be totally unable to distinguish between the relative sizes of the two objects, or form any estimate as to the distance away of the house. Readers should try the experiment of looking at a scene with one eye only.

Take an ordinary photograph. It lacks solidity and depth. If it represents a familiar scene, then our experience enables us to visualise the scene in its proper proportions. If the scene is a totally unfamiliar one, then it is impossible for us to gain from a photo-

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graph a true idea of the scene or object which it represents, and this is especially true as regards its proportions. It is for this reason that certain unfamiliar objects, such as the anchor of the world's newest and largest ocean liner, are usually photographed in conjunction with a familiar object. For example, an anchor is usually photographed with a man standing beside it, in order to convey in a manner otherwise impossible a true impression of the immensity of the anchor.

Normal vision shows us objects in relief, so that we can judge distances and sizes, and tell at once the difference between a photograph of an object and the object itself, in that one is merely a flat subject, whereas the other has depth. This effect of depth and relief is due principally to the fact that our visual impression is a *combination of the images seen by our two eyes.*

The left eye sees a slightly different view of any object to that seen by the right eye, and the brain combines these two slightly dissimilar views to give us an impression of solidity and depth.

In the once familiar stereoscope, advantage is taken of this principle in order that a photograph may be reproduced in a life-like manner. Two photographs are taken simultaneously by two cameras (combined in one case), the lenses of which are separated by a

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distance equivalent to the separation of the two eyes, which is about four and a half inches. These two cameras, therefore, produce two photographs of the same object, from a slightly different point of view.

The finished photographs are then mounted side by side, and viewed through a combination of prisms, which have the effect of making the right eye see only the photograph taken by the right-hand camera, and the left eye see only the photograph taken by the left-hand camera, and of superimposing these two images. We then gain an effect exactly similar to that obtained by viewing the object itself, i.e., we see, not an ordinary flat photograph, but, as it were, the actual object or scene itself.

The great advantage of stereoscopic photographs, viewed through a stereoscope, is, therefore, that we gain a really true-to-life impression of the scene being viewed. By adding colour photography to the process, the scenes, viewed in their natural colours, take on a startlingly realistic appearance. Perhaps the most valuable application of stereoscopy, however, is in connection with range-finding for artillery or other purposes.

By applying these principles to television, Mr. Baird succeeded, as mentioned in the opening sentence of this chapter, in trans-

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mitting television images in stereoscopic relief. The stereoscopic effect is obtained by sending two images alternately, one image corresponding to that seen naturally by the left eye of the observer, and the other to that seen by the right eye.

At the transmitter a disc containing two separate spirals of holes is used, one spiral being near the periphery, and the other spiral four and a half inches nearer the centre, so that the two spirals are separated roughly by the distance between the two human eyes. The arrangement is shown in Fig. 36, where B indicates a disc laid out for stereoscopic television in monochrome, and A represents a disc with two triple spirals, as required for stereoscopic television in colours. In the latter case the holes are covered with appropriately coloured filters, as described in Chapter XIV.

Two lenses are employed to bring to a focus the beams of light from two light sources, so that the object the image of which is to be transmitted is traversed alternately by a point of light projected from the left-hand lens, and then by a point of light projected from the right-hand lens. The light reflected back from these points falls on to a photo-electric cell, or battery of cells, which transform the light impulses into electrical impulses, which are transmitted to the distant

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receiver, after amplification, in the form of an undulating electric current. A plan of the transmitter layout is shown in Fig. 37.

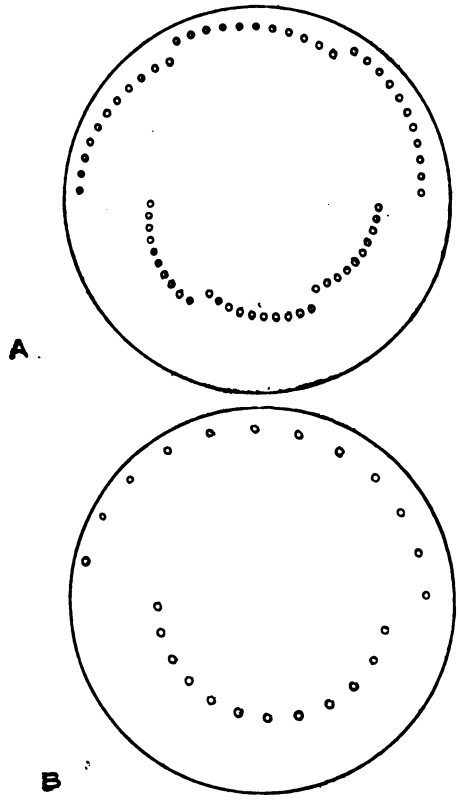


FIG. 36.—DIAGRAMMATIC REPRESENTATION OF DISCS USED FOR STEREOSCOPIC TELEVISION.

Disc B is arranged for television in monochrome. Disc A is provided with two triple sets of spirals for stereoscopic television in colours.

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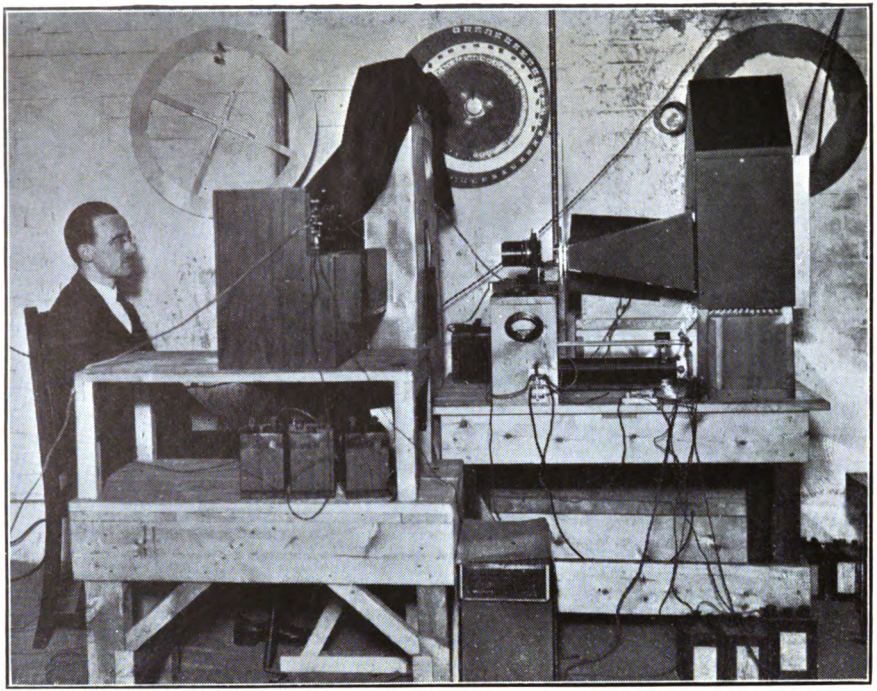

THE EXPERIMENTAL STEREOSCOPIC TELEVISION TRANSMITTER IN THE BAIRD LABORATORIES.

The light sources are on the right, while the disc (shown edge on) revolves just behind the lenses. The photoelectric cells are mounted in front of the sitter, shielded from direct light from the light sources.



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At the receiver a disc geometrically similar to that in use at the transmitter revolves in step with the transmitting disc, so that two images appear side by side on the receiving screen, one image corresponding to the object as seen by the left eye, and

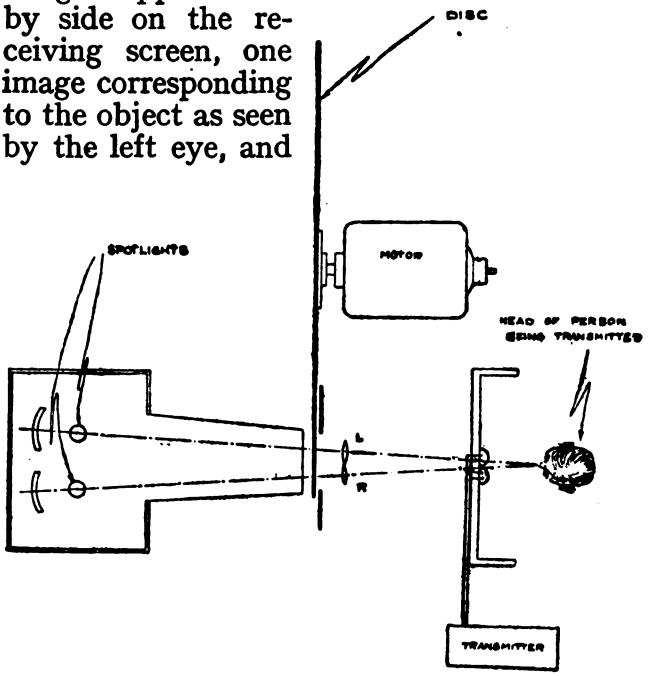


FIG. 37.—PLAN OF THE ARRANGEMENT OF THE STEREOSCOPIC TELEVISION TRANSMITTER.

The rotation of the disc causes the sitter's head to be traversed by a point of light issuing alternately from lens L and lens R. The photo-electric cells, immediately in front of the sitter's face, pick up the light reflected from his face, and transform it into electrical impulses which are transmitted to the receiver.

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the other corresponding to the object as seen by the right eye.

These two slightly dissimilar images combine when viewed through a stereoscope, so that the observer gains an impression of stereoscopic relief and solidity. A plan

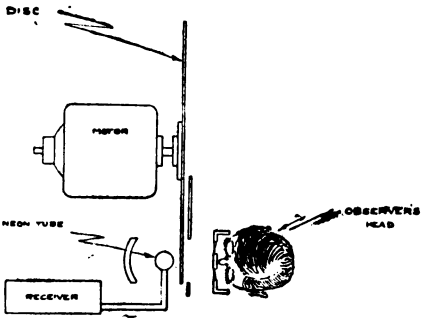


FIG. 38.—PLAN OF THE ARRANGEMENT OF THE STEREOSCOPIC RECEIVER.

A disc similar to that in use at the transmitter is employed. The observer looks through a stereoscopic viewing arrangement, and through the two sets of spiral holes in the disc, at the fluctuating brilliancy of the neon tube behind the disc. Two images are formed, which blend together when looked at through the stereoscope. For stereoscopic television in colours, two sets of red, green, and blue images are transmitted and received successively, the combined effect on the retina being that of one image in natural colours, in perfect stereoscopic relief.

view of the receiver is given in Fig. 38, which portrays an observer watching the fluctuating brilliance of the neon tube through, first, a stereoscopic viewing arrangement, and second, through the two spirals of holes in the revolving receiving disc.

At the demonstration of stereoscopic tele-

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ONE COMMERCIAL FORM OF THE BAIRD TELEVISOR, FOR HOME USE.

Behind the grill on the left is a loud speaker. The image of the head and shoulders of the distant speaker or singer appears on the screen at the right.



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vision previously referred to, the image of one of the laboratory assistants was very clearly transmitted in perfect relief. The author, who was present, could not help being struck by the extraordinary vivid and life-like appearance of the stereoscopic image, as compared with the ordinary " single eye " television image. In the opinion of all present, including several prominent scientists, the experiments promised considerable development and importance in their practical application.

The enormous possibilities of television, especially when used in conjunction with invisible rays or gramophone records, or as adapted to the transmission in their natural colours of scenes illuminated by ordinary daylight, stir the imagination and open up long vistas crowded with marvellous visions, far transcending the potentialities of even the fabled Magic Carpet.

Today we sit at home, turn a dial, and listen to speech, music, and native sounds from far-distant lands.

Tomorrow we shall, by an equally simple action, be able to bring into our homes not only the sounds but also the sights of these lands, faithfully reproduced in their natural colours. Add to this the ability to witness these scenes in stereoscopic relief, and we may well rub our eyes and wonder if we have not,

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by some form of magic, been personally transported right into the very midst of the scenes which we shall see on the screen of our stereoscopic colour televisor, and the sounds of which we shall simultaneously hear through the medium of our loud speaker.

THE END

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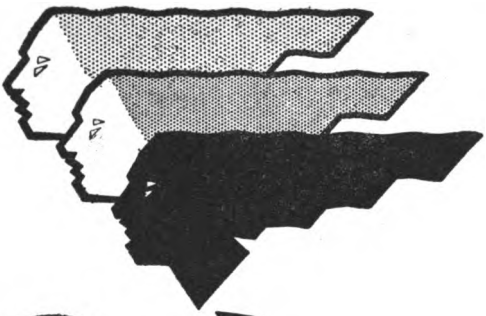

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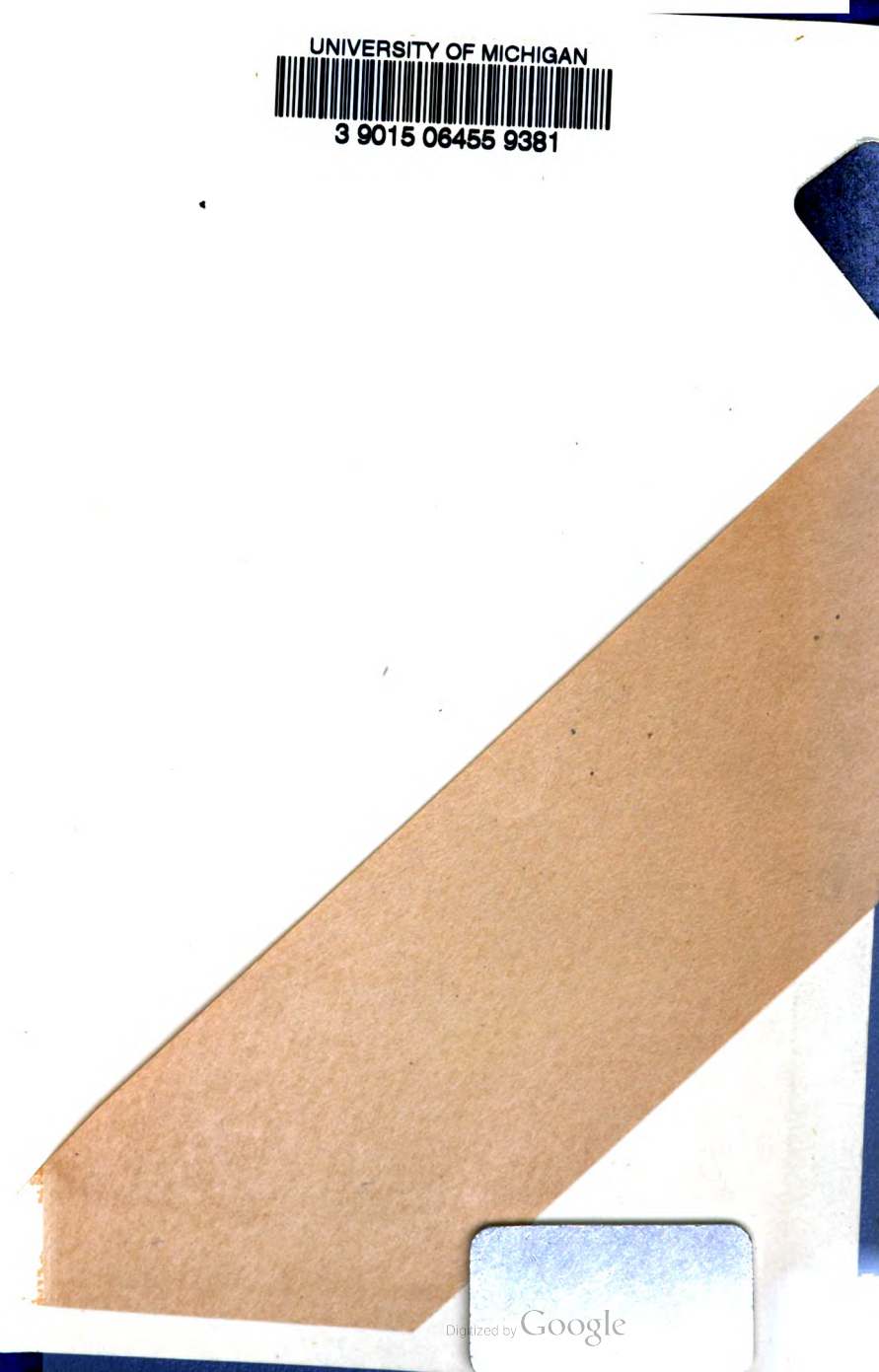

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